# Interaction Design for Situated Media Production Teams

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**Abstract**

Media production teams are the backbone of many media industries including television, sport gatherings and live music events. These domains are characterised by a key set of situational factors which significantly impact on the collaborative production workflow, such as temporality, professional concerns and mission criticality. The availability of new interaction technologies presents an opportunity to design systems to support these teams in these complex environments, leveraging the affordances of interaction technologies in response to the situated factors that impact specifically on these types of domains. StoryCrate and ProductionCrate, two large-scale real-world prototype systems for supporting situated media production teams were designed and deployed to explore the interaction design considerations that could support these teams in specific scenarios. Through an extensive analysis of these deployments, key design considerations, interaction techniques and modalities are presented that can be developed in response to the situational factors found in collaborative media production environments.

## Publications Arising from Thesis

***The following publication forms the basis for Chapter 3, the design and implementation of StoryCrate:***

Tom Bartindale, Alia Sheikh, Nick Taylor, Peter Wright, and Patrick Olivier. 2012. StoryCrate: tabletop storyboarding for live film production. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12). ACM, New York, NY, USA, 169-178.

***The following publication forms the basis for Chapter 4, an evaluation of StoryCrate:***

Tom Bartindale, Elizabeth Valentine, Maxine Glancy, David Kirk, Peter Wright, Patrick Olivier, 2012. Facilitating TV Production Using StoryCrate. In: Proceedings of Creativity and Cognition 2013. ACM Press.

***The following publications arise from my work with tangible and multi-touch interactive technology development, which informed the design of the technologies in this thesis:***

Hook, J., Schofield, G., Taylor, R., Bartindale, T., McCarthy, J. and Wright, P., 2012. Exploring HCI's Relationship with Liveness. In: *Extended Abstracts of CHI 2012*. ACM Press, pp. 2771-2774.

Schöning, J., Hook, J., Bartindale, T., Schmidt, D., Oliver, P., Echtler, F., Motamedi, N., and Brandl, P. and von Zadow, U., 2010. Building interactive multi-touch surfaces. In: *C. Muller-Tomfelde, ed., Tabletops - Horizontal Interactive Displays.* Springer-Verlag, pp. 27-49.

***The following publication introduces situated media production and StoryCrate draws from the tangible and team collaboration concepts developed during the following research:***

Tom Bartindale, Jonathan Hook, and Patrick Olivier. 2009. Media Crate: tangible live media production interface. In Proceedings of the 3rd International Conference on Tangible and Embedded Interaction (TEI '09). ACM, New York, NY, USA, 255-262.

***Publications arising from Chapters 5-7, relating to ProductionCrate are currently in submission.***

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# Chapter 1. Behind the Scenes

## 1.1 Video Production In the Wild

Media that is consumed through TV, live events, and the web is generated by teams of creative people with a variety of skills working together to produce a directed output. Often this team is situated within a specific venue or location, producing content for audiences within a bounded timeframe. Activities such as TV production, live theatre, music concerts and organised social events all fall within this type of situated media production. Although the medium of their outputs differ (lighting, sound, video, engagement, written content), these domains all require situated media production teams who operate production technologies to produce output media.

Figure 1 shows a typical live video production desk belonging to a situated media production team at a week-long faith based conference event of around 5000 attendees. When arranged by a faith organisation such as 'The Salvation Army' such events see attendees congregate to a specific town over 3 – 5 days. During this time, presentations, worship sessions, singing and entertainment are planned into a full programme of events across multiple theatre and conference venues throughout the town. In each venue, a team of eight engineers and operators shoot, mix and record four video cameras and three PC sources to produce a video feed displayed on screens and TVs throughout each 1500 person venue. Camera footage is overlaid with song lyrics for singing, alert messages are displayed to gain the attention of particular attendees, and text messages are routed to the display alongside videos and presentations from speakers. In each venue, four of the crew sit side by side at a desk located at the rear of the venue (Figure 2) in an order dictated by the linear equipment workflow and physical connections (See Figure 1). On the left sits the chief video director. Their role is to direct the video production team according to a scripted running order. This includes cueing videos for playback, managing incoming twitter and mobile feeds and communicating with members of the venue crew such as the stage manager and lighting engineer. Next sits the video playback operator, who controls a large number of different technologies including VHS, DVD and HDD media players and PC playback software. To the right of the playback operator sits the song lyrics controller. It is her responsibility to monitor and operate the text overlay system, using a specialist PC application[1]. To the right of the song operator sits the video mixer operator who is responsible for taking the feeds from the other two operators, along with camera feeds from across the venue, using a digital video mixer[2] to output them to displays located within the audience and on stage. In intense situations, tasks are often shared between the director, the media playback operator and the song words operator, but the video mix operator is always left to independently operate their own task. A bank of small video monitors shows all possible input feeds available for mixing, and often the mix operator only has a view of the stage through these displays. This mixer operator is in radio contact with three manual camera operators located across the venue, guiding and directing camera shots every one to five seconds using a controlled language of short-hand voice commands. Indeed, throughout the course of the entire production the video production team are in constant contact using voice communication sets[3] and are aware of each-others actions. The director also maintains voice communication with the venue crew using a separate voice channel, representing the video team. This team was required to install, connect and test all of the video equipment for their venue in the afternoon prior to the first day of the event. The team then operated this technology from 9am until 8pm for four days, followed by dismantling the equipment on the last evening for transport to another town. Although each session in the event is partly scripted and has a running order, the fluid and responsive nature of the event means that changes in both content and technology must be accommodated dynamically. Often speakers arrive late with incompatible media for playback, or arrive in the venue minutes before their scheduled appearance on stage, with a presentation that needs displaying during their appearance. Often these spontaneous content additions occur during other mission critical periods such as during songs. The director is sat in a position to intercept people communicating with the video team, physically filtering information to avoid cognitive load on the other team members.

[1] http://www.wordsofworship.com/

[2] http://business.panasonic.co.uk/professional-camera/3d/ag-hmx100

[3] http://www.tecpro.co.uk/


***Key***
*a) Director's seat, b) Media playback and information message creation, c) Song lyrics controller, d) Video mixer and camera controller.*

*Figure 1 The live video routing setup at ECG 2009 (Llandudno, Wales) – Located at the rear of the venue, the director, media controller and camera mixer sit here. Control technology is arranged linearly in the order that video passes through devices.*

## 1.2 Team-Based Situated Media Production

My brief "backstage" account of the ECG 2009[4] event illustrates a particular context and workflow for a situated media production team. In this case, a team is tasked with producing a live video stream to members of the audience in one of three large venues. The team route live video mixed with song lyrics, informational and supporting content to assist the audience in both viewing and engaging with the event.

[4] http://www.ecgevent.org.uk/

Collaborative media production is not limited to community participation events[5] such as these, and although often based around a 'live events' such as rock concerts, production teams also operate in many other complex media production settings where the dynamics of an event's "liveness" (and the collocated audiences experience of this) is not the key constraint. Television and film production, sports events and theatre productions are all environments which involve team-based situated media production. As I further elaborate in the following sections, this inquiry focuses on productions related to discrete events or activities taking place at a specific location (or set of locations), and within a well-defined time bound, in which production teams work collaboratively to create, produce, curate, maintain and/or distribute media content to a variety of participants.

Technology innovation in production technologies takes many forms, including advances in camera technology[6], digital production tools[7] , tapeless production (Cunningham & de Nier, 2007) and mobile production tools (Wired, 2012). Understandingly, much of this development has occurred within the assumptions and practices of professional production team practice, and technologies and tools generally correspond to incremental steps that optimise or deskill elements of the existing production workflow. However, while professional technologies are grounded in a rich understanding of individual media production team roles, by contrast, this inquiry investigates the role of interactive technologies to augment the production team as a collaborative activity so as to improve the overall production workflow.

Furthermore, despite the long history of research into technologies that support creative collaborative teams, such as those found in situated media production, even within the computer supported collaborative work (CSWC) research community few in-the-wild explorations of team-based media production have been reported. The availability and known affordances of interactive technologies for collaborative work

[5] Community participation events are arranged around a particular interest group, often using members of the group as organisers and crew.

[6] http://www.red.com/store/cameras

[7] http://www.bbc.co.uk/rd/projects/ip-studio

now provide the opportunity to explore team-based media production through real-world design and deployment studies.

This thesis investigates how collaborative interaction technologies can enhance aspects of team-based situated media production, both through feasible innovations in workflow and by addressing situational factors that are inadequately addressed by existing technologies. My approach has been unpick these situational factors through the process of designing and deploying two case studies and distil these as a discussion on designing interactive technologies to facilitate elements of production team practice in these situated collaborative media production scenarios. In the first case study, **StoryCrate**, a TV production tool for on-location filming is designed and deployed to explore issues around the facilitation of team-based creativity in a TV shoot scenario using collaborative, tangible, table-top technologies. In the second study, **ProductionCrate**, a distributed media production system for 'live community events' is designed in response to the complex task of deploying media-rich content in a conference style event environment to drive engagement between attendees and event content. Even within my limited characterisation of team-based media production, bounded by event, location and time, the diversity of media production teams, their goals, and the situational factors within which they operate is substantial.

## 1.3 Media Production Technology

The processes of media production are well understood (Verna, 1987) and there is a history of research within HCI into media production workflows and teams, such as those by Engström (Engström, Esbjornsson, Juhlin, & Perry, 2008). While this has influenced the design of new production technologies the historical focus has primarily been on broadcast related production environments. In the past decade, with the development of faster, cheaper digital production tools and audio and video processors, there has been a shift in the nature of situated media production technologies from expensive bespoke equipment, for example, as we might have seen in National Theatre in the early eighties (Brett, 1979), towards desktop computers and IP based media infrastructure (as is now widely used in modern provincial theatres (G. Richards, 2008)). This transition away from bespoke technologies has the consequence that new technologies and systems can be more readily deployed within media production environments.

In recent years, media production tools have become available in consumer products such as mobile phones and manufacturers of professional production tools are engaging non-professional consumers by offering limited functionality versions of their products. Even with the convergence of consumer and professional production technology and the move to standardised digital platforms, introducing new technology into production environments is an expensive proposition, as such significant changes in technology and workflow practice are rare. Building on the theory of ‘industrial divides’ discussed by Piore and Sabel (Piore & Sabel, 1984) in which industrial technologies develop in parallel to consumer products, Starkey and Barnatt postulate that the introduction of networking infrastructure and flexible content distribution in the broadcast industry in the late 1990’s is one such example of a turning point for the deployment of a critical mass of new technology into real world production environments (Starkey & Barnatt, 1997). The introduction of collaborative interaction technologies such as multi-touch, tangible, table-top and mobile technology a decade later could be viewed as the pre-cursor to another such turning point.

Using new forms of interaction technology such as multi-touch displays, tangible interfaces and 3D tracking technology, we are now able to design and develop for production domains with these new modes of interaction and configurations of actors. Building on the technology that now exists to support the functions of these complex workflows, production teams are already starting to overcome limitations of current tools by making use of interaction modalities such as mobiles (Jokela, Karukka, & Mäkelä, 2007) and touch screen interfaces for editing. However, less emphasis has been placed on the use these tools to support collaborative elements of the workflow. There is still much potential for tangible and embedded and mobile interaction technologies to support production teams, especially by augmenting the collaborative processes involved across media production teams with designs drawn from newly available collaborative interaction technologies and design practices.

## 1.4 Situational Factors

Situational factors characterize the design challenges for technology innovation in media production scenarios and define the primary design constraints for supporting collaborative interaction within situated production teams. Many situational factors are shared across media production scenarios, and each production scenario presents a unique combination of these factors. These factors have a broad impact on key elements of the production workflow including: the physical environment of the team, the hardware and technology required to perform roles, the team structure and measurement of success. In practice these factors are complex, inter-connected, and can combine to produce unexpected situational and workflow challenges for team collaboration. Many factors can be represented by a spectrum onto which all media production environments are present, and as such it is vital to understand these factors in relation to their effect on specific production scenarios. Historically these challenges drive the development of new workflows and technologies to facilitate production, and as such characterise the production scenarios and related technology into which StoryCrate and ProductionCrate are deployed.

### *1.4.1 Team Members*

Current situated production teams are highly dependent on automated tools and equipment as part of their workflow, but even with such in-depth integration of production technology and processes, there still exists a necessity for human control over these tools. Skill, judgement, experience and creativity all come from members of the team that operate these tools as part of the production workflow. These technologies often require years of practical experience to engage with their nuances, with the result that operators are often emotionally attached to particular types of device. The range of experience and knowledge in many production teams presents challenges for developing media production technology to support multiple skill levels whilst facilitating both amateur and professional crew effectively.

Traditional media production scenarios are split into the roles of an ‘audience’ who consume a media product generated by a ‘production team’. This dichotomy is standard practice for live events such as musical concerts, but in other scenarios these two roles become less defined. In production scenarios for recording such as studio TV production, often no audience is present at the location or at the same time as filming whereas in ‘community’ productions such as amateur dramatics and faith events, production crew may also consider themselves members of the audience (and therefore consumers of the content and experience). Therefore it is detrimental to categorize all actors[8] in a production environment into these two distinct roles without considering the nuances of their own perceived experience. Consequently it is important to understand the relationships between team members, their environment and the media they produce. Key factors when exploring this relationship include: the perceived relationship the actor has with the generation of content; the expectations these actors have of the production workflow, and the output produced; the stake that the actor has in the successful outcome of the production.

In situations lacking a live audience, such as TV production, often the actors, production crew and director move between consumer and producer roles to experience and then gauge the quality of their own work. Performers on set would consider themselves producers of content, but the production crew may perceive them as participants, with an equal stake in the output produced. Similarly, stakeholders in the production process in community based events are simultaneously participants and production staff. In these events, a few members of staff are paid, but the majority volunteer their services in return for a personal link to, or experience of, the event, and maintain an affinity to the audience whom they relate to. Often venues, production companies or even manufacturers will maintain their own production teams which can lead to a range of expectations of a successful output. For example, a representative from a manufacturer will consider a production successful if their equipment works correctly, but will not be concerned about the creative product, as the director would be. In all circumstances, teams must work with them to produce a singular event or output, rising above their individual justifications and particular team practices.

### *1.4.2 Professional Considerations*

Usually the variety of skills and experience found in a production team translate directly into a management structure which reflects this natural hierarchy, but this may not always be the case. Social stigmas can be attached to particular production

[8] An actor in the environment rather than a theatrical actor

roles which surpass their assigned managerial position, such examples of these roles include the ‘Sparks’ (electrician) on a film shoot, or the stage crew in a theatre production. The technical roles performed by production crew are often complex and require years of experience and training to perform correctly and efficiently. Specific technologies are often associated with particular crew roles (e.g. the camera for the camera-man), with team members trusting in each other’s abilities and instinct to perform integrated tasks without knowing how to perform the role themselves. In smaller productions such as low-budget films, team members multi-skill to save money, sharing technical and managerial roles across the team in response to the dynamic demands of the shoot. In larger scenarios, where team members are hired for specific roles, there may be an adverse reaction to this very practice and as such multi-skilling would be discouraged on professional grounds. In practice, most team members will have skills and experience in other roles (for example camera operators also being editors), and subsequently use their own experiences of these roles to improve their practice and interaction within the team.

Team members are often in teams with others whom they have no prior working experience. New working relationships rely on a level of trust to exist based solely on the experience and judgement of other members of the team. Similarly, trust in the equipment they are operating is an important factor in this scenario so consequently many freelance production crew own and maintain their own equipment. Introducing new or unknown equipment into a workflow can lead to miss-trust and resentment towards technology which may be seen to remove or replace existing team roles. Self-classification of a crew member (rather than explicit managerial arrangement) into a team hierarchy often leads to unexpected channels of communication amongst the team, with personal trust circumventing hierarchical operating procedure. Although often more efficient, this can cause communication failures if a team-member is unknown to the group, and trust in their abilities has not been collectively established.

Each member of the production team has a stake in the outcome of the media produced, but this may vary between individuals. Paid professionals will hold their professional reputation to scrutiny with concerns over production quality with regards to successful payment for a task, but may hold no direct concern of the audience’s experience. Crew members based in a venue represent the venue in all matters, and must act accordingly, although each individual visiting production may not concern them regarding content, the resulting consumer experience drives their work. In some cases, the production team is led by a group of creative practitioners with a collective crafted vision. These individuals respond to failures and successes personally, often taking financial burden or social risk themselves. Often un-paid runners, interns or other interested parties form part of the team. They perform un-skilled tasks with the intent of learning future skills, participating and are often a member of a related event community.

### *1.4.3 Technology*

Media production technology evolved in a symbiotic relationship with the production workflows and teams that operate within them. Incremental advances in technology drive equipment designers to find new ways to accomplish workflow tasks, whilst emerging workflow practices drive the need for technology to effectively support them. Key advances such as file based production and mobile production technology are rewarding technologies that have arisen from this relationship, but tools to support collaborative work between team members are still limited in availability. Crew specialization with specific technology is reflected in team structures, where management and communication hierarchies are built to support the affordances of particular technologies: for example the linear relationship in a live video production team that has evolved in response to multiple single-user linear video routing devices being connected end-to-end. Crew are now working more independently, supported by individually targeted technology and the awareness of other roles and responsibilities within the team has degraded and crew members are associating themselves with particular factions of the production world related to specific roles rather than the production environment as a whole. Politically, these factions are represented by trade unions of specific production workers. These social factors have the side-effect of reducing the multi-skilling of team members, and has often removed the need for more collaborative (and creative) workflow practices. One such example is the phase-out of storyboards from TV production when a cheaper celluloid replacement was widely implemented. Storyboards have been replaced with a shoot order which is distributed to each team member individually.

Technology plays an integral part in the decisions made by production crew as often entire production installations contain a single brand of equipment to guarantee interoperability. The reliance on specific brands or types of equipment prevents the easy acceptance and assimilation of new technology into the production workflow. By understanding the clear link between a crew members experience with specific technology and their career prospects, it is clear how technology has evolved to be primarily targeted at single users.

Many production interfaces already make use of design attributes such as physicality and tangibility that have been highlighted by HCI researchers as key elements of interaction design. Although the majority of production tools are now computer based, most present a set of single user physical controls to the user for manipulating properties during the production process. A live sound mixing desk is such an example of a tangible computerised single user interface. Although moving towards standardised connection technologies such as IP networking, it is still the case that many integrated production solutions rely on proprietary or legacy equipment. This equipment often has particular workflow or physical constraints, or include controls that need to be monitored and adjusted constantly according to specific nuances of the equipment. Many standards exist for production technology integration, such as DMX[9] for lighting control and VISCA[10] for camera control, but these systems enforce a particular workflow and technology topology on the production team. Many consumer products now share the same production workflows and processes as professional tools, and as such, professional production tools can benefit from a social knowledge of media production present in society, especially for newcomers to production work. Within production environments however, the consequences of technology failure are larger than the consumer world, and as such consumer products often implement new technologies faster than in production. Many media production teams rely on specific older technologies even though newer more efficient alternatives exist to avoid the chance of unknown problems occurring during a production. Consequently any new technologies deployed within situated production environments where these existing

[9] http://en.wikipedia.org/wiki/DMX512

[10] http://www.chuktech.net/video/ViscaProtocol.pdf

technologies are used must be able to integrate transparently with these systems. Practitioners in live production are used to operating complex interfaces alongside multitude of different other practical tools and devices. This pre-disposition to technological innovation and the existing base of knowledge and skill for using digitally enhanced interfaces provides a unique opportunity to deploy prototypes into an environment without a significant burden.

### *1.4.4 Liveness*

Media production environments are often synonymous with live event productions such as weekend music festivals and live theatre performances. These 'live' events require a different measurement of production credibility compared to that of a non-live event such as TV filming. It is these credibility factors that often form the basis of an attendees' opinion on the 'quality' of the production and their experience of it. An event designed to provide a live experience, with participants or audience members often paying for the opportunity to attend a specific location can be described in terms of its 'liveness' (Auslander, 2008). For production teams, their role in creating an experience of 'liveness' varies between scenarios: in a concert or theatre production setting, where there is a definite separation between audience and production, the crew are expected to remain hidden. Loss of production value is perceived when these team members are observed, or when 'mistakes' occur during the production. Ironically it is often these mistakes that prove to the audience that the event is actually live (and not a pre-rehearsed script, recording or dubbing). In contrast, if an event is founded on the participation and involvement of members of a community, such as at an academic conference, the visibility of the production crew creates an air of professionalism and support for attendees. In many 'live' events, much planning goes into creating the *appearance* of liveness, such as location specific dialog for travelling shows, or *spontaneous* encores at the end of a performance. Thus it is the *perceived* liveness of the event by the audience that the production crew is working to produce and maintain.

'Liveness' is directly linked to elements of perceived risk found in situated media production workflows. In a truly live scenario such as a music concert or conference talk, every action that a production member performs affects the experience of a large number of other people (the audience). In these immediately responsive scenarios, decisions must be made quickly and with good judgement to maintain a high production value of the event. In these scenarios, significant repercussions exist for the production team when failing to perform effectively, as problems have to be rectified immediately and on-site and must meet the expectations of the audience. As a result, some media production scenarios are built to minimise production risks, for example TV production shoots, which are bounded by time and financial pressures, but allow for rehearsal, re-takes and multiple attempts at production tasks before recording. These levels of risk lead to high pressure and cognitively loading environments for production teams, in which many tasks have to be performed in quick succession in response to unforeseen events. In these instances, a human element in the production chain is an essential requirement, as critical decisions take judgement and contextual understanding gained from past experience to perform correctly.

### *1.4.5 Coordination*

All production environments follow a timeline, work plan, running order or script of some form which informs the production team what tasks need to be addressed. This guides the team towards a central goal, allowing them to react efficiently to each other and the production as it evolves. Production scenarios follow a variety of scripting models, each with the expectation that the script will enforce of levels of control over the timing and content of a production and the production team interpret this script according to the production tasks required for each segment. In a TV shoot, the order in which camera shots will be setup and captured is defined by the 'shoot order' (a type of script), but this is only a reference guide as to what should be completed by the end of the shoot to satisfy the editor. Conversely, in a live media production such as a theatre performance, the script is treated as definitive, and no scope is given for moving away from its instruction.

Unlike pre-recorded content, in live events such as musical performances, there exists an inherent danger of deviation from the pre-arranged running order plan, putting the production crew in the position of having to make key decisions, take timely actions and communicate changes in order to bring the event back onto the original plan. These deviations from the running order, although sometimes predictable, lead to unexpected workflows emerging from the production team as they respond to dynamic changes usually instigated by stage performers. In such instances, the production benefits from the expertise of experienced members of the team who require less detailed guidance from the running order or script, instead using their own judgement of situations to respond quickly.

As Auslander describes, the spontaneity of the performers and deviation from the script within the live context is often what is perceived by the audience as ‘live’, and a balance must be struck between producing an event perceived as ‘perfect’, and providing a valued an unique experience for the audience. This balance between perceived spontaneity and scripted content is something that improvised theatre has been tangled with since its inception, and offers some unique insights into methods of managing script divergence and placing boundaries on risk during the production (Guay & Dinsmore, 2010).

The existence of a script does not necessitate rehearsal in a production scenario, as often a script is merely a description of the expected deviances from the normal production process that might be experienced during the live production, for example the possibility of an encore at a rock concert. Conversely in theatre production, the script is continually edited throughout rehearsals to match changing directorial decisions, so that it represents an accurate and exact description of the expected production process.

Coordination of intent and status between team members is a necessity for a production team to perform their roles. Crew members may not be physically located nearby, or even within the same venue, so voice and written communication lexicons (e.g. camera control verbs, script tramlines) have evolved to support rapidly communicating intentions between co-located and disparate team members. Although the use of these standard protocols necessitates knowledge by all members of the team, this enables crew joining from other production environments quick integration into the workflow. Particular production environments have evolved specific spaces in response to the communication constraints of the production workflow. TV studios are examples of spaces that bring all production crew into a single building, providing integrated voice communications, video and audio links between spaces and allowing for infrastructure such as lighting to be permanently installed. Temporal factors affect the organisation of media production teams. In longer running events such as conferences (1-2 weeks), team members will experience long periods with few responsibilities, interspersed with short periods of extreme cognitive load requiring production skill and finesse. In theatre productions, often no production skill is required to operate technology during a performance as all complex actions were pre-prepared during technical rehearsals. The crew are primarily present in case of equipment failure or deviation from the script. In shorter events such as TV production (2-3 days), crew members are heavily involved in the production process for the duration of the event.

The time available transport, installation and configuration of production equipment are variable and often linked to environmental conditions such as the need to move between venues and often require 500% - 800% of the creative production phase for setup. Within these temporal constraints, production equipment must deploy and configure in predictable or standardised ways, so that hardware failures can be quickly resolved. In such short setup times, the consequences of production technology failure are critical, especially if the production is centred on a particular event in time which cannot be postponed (such as a concert). As discussed, the configuration, experience and abilities of an interdisciplinary production team dictate the structure of the team hierarchy, with smaller teams tending to a flatter management structure. Specific environmental factors associated with the production scenario play a role in the configuration of these teams, particularly if rapid response to unforeseen events is required. In these cases, the team may be split into smaller ‘rapid response’ teams, containing a range of skills but without a physical based of operation.

### *1.4.6 Environmental*

The physical environments in which situated production teams work exhibit specific situational factors which influence the production workflow. Venues may be very dark and noisy, such as at rock concerts (Figure 2), which negate the use of visual or verbal communication, but conversely may require complete silence as at a classical theatre production. Production technology has evolved with these constraints impacting on their design. Such equipment makes use of physical buttons, sliders and actuators for controlling key functions, providing kinaesthetic feedback of actions. For example, lighting desks are still operated with physical ‘sliders’ which enable the operator to look up to the stage onto which they are directly manipulating lighting. Production environments may also experience extreme heat, cold or weather conditions, such as when filming wild-life documentary footage, thus technology in these scenarios requires physical ‘ruggedisation’, weight reduction and long-life battery supplies. Production spaces often employ hot lighting under which the team must work long hours with little rest.

Spatial constraints within the environment can enforce specific physical configurations of team members and equipment, for example the need in a concert venue to place the sound desk in a position where the majority of audience members are located so that the operator can mix for the largest consumer group, or conversely locating the video editing desk of a sports event physically outside of the venue so that directors are not distracted by views that the viewer cannot experience through live footage. The consequence of these role specific positions is that production crew are physically located at the extreme limits of the venue relative to each other, and often removed from the rest of the production team. At a live music event, for example, the lighting operator would be located in a position where he enjoys the best possible view of the stage, (the elements of production they have direct control over), but such a good view may not be possible in many scenarios due to space constraints or lack of line-of-sight. In addition to responsive reconfiguration of equipment and crew members, teams are often structured in response to their environment. Teams can be split into hierarchies depending on physical location (e.g. across multiple buildings), size of the team or distance to the director (using assistant directors to communicate with a larger team), or given multiple roles to compensate for a lack of team members in a given location.

In many production scenarios such as those based outside of custom venues, space is at a premium. Often TV locations are within small enclosed spaces with little room for equipment and personnel. This has beneficially led to the development of smaller and more portable equipment such as cameras and monitors, but large amounts of equipment such as lighting still have to be transported and configured in these locations.

Many production teams negotiate unfamiliar venues on a regular basis, and at each venue, a pre-planned production must take shape to match the directors vision created during rehearsals. Venues differ in size, shape, technical configuration and availability of infrastructure and equipment, and often providing their own 'in house' production team with experience in the nuances of their venue. For a touring band concert, the stage is dressed with set, lighting, sound, video and special effects equipment that is transported to each venue on the day of the event. There is little time to disassemble the equipment in one venue before transporting and re-assembling it in another within 24 hours.

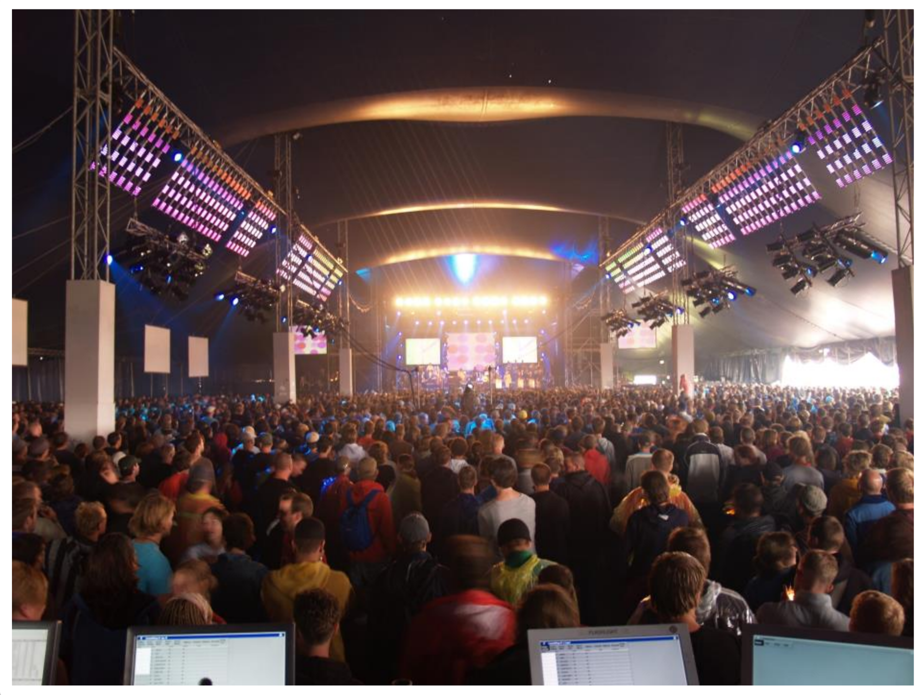

*Figure 2 A Live Music Concert – The view from the lighting desk located at the rear of the venue.*

In these scenarios the production team workflow revolves around the use of particular configurations of equipment organised during rehearsal that travel with a production. In TV and film productions, often the crew having many weeks to prepare a location or venue for production which subsequently runs for many months before equipment needs to be dismantled. Unlike a travelling production, each production configuration is bespoke and will not be replicated once dismantled. Such travelling production systems are enclosed in heavy duty enclosures and wheeled cases, presenting robust physical design features and standardised fixings and fittings to support repair on the move. These devices are often self-contained, so that individual components are easily located and connected for assembly and transportation.

## 1.5 Improving Production

In any media production there is always the opportunity for improvement of both the output product, and the production workflow. In this thesis I hypothesize that by augmenting existing situated media production workflows with integrated collaborative interaction technologies, these areas can be improved. In the production industry, the notion of improvement is often synonymous with increased efficiency and lower costs. With the availability of file based production and portable editing systems, production teams are now obligated to produce media which meets high continuing standards with fewer crew members and lower budgets.

The cases studies herein utilise two different methods of measuring improvement. The history of TV production and financial pressures in this highly contested industry are such that the situated production workflow is already a streamlined and efficient process. Through evolving to this efficient state, the opportunity for creative input across all levels of the production team has degraded in favour of cost saving, single-skilling and a reducing the time to market. **StoryCrate** was deployed to facilitate and improve the creativity of the TV production team, introducing opportunities for collaborative and creative working with content during the shooting phase of a production. Conversely, **ProductionCrate** was deployed in a community event scenario which values responsiveness and contextual understanding of socially produced media. It was designed to drive social connections and engagement with conference media streams, using a contextual media routing platform to drive participation. In this case, enabling non-professional team members to perform complex production roles was a key measurement of improvement.

To deploy technological prototypes in real world production settings, it was vital that each situated production scenario presented a logistical and technically feasible deployment opportunity within the constraints of a research project. For a production team to allow the deployment of new technology into their workflow, a trusting relationship would have to be established with the researchers, subsequently limiting deployment opportunities within the available timeframe. Each case study would require a development period an in-the-wild deployment and the ability to perform a succinct end-to-end study of a production context. A short succinct deployment was beneficial to encourage a sense of completion for the production team involved and result in a complete timeline of interaction for evaluation. Short-term deployments in which the production produces a discrete meaningful output bounded by time constraints e.g. the event dates, or broadcast date were an appropriate choice for case studies.

### *1.5.1 StoryCrate*

Chapters 3 and 4 of this thesis describe the design and deployment of **StoryCrate**, the result of a collaboration with BBC Research. Broadcast is one of the only situated production scenarios that has peaked research interest, and so is a key place to start an exploration of collaborative interaction technologies within situated production workflows. Short TV production was presented as a viable case study due to the support and interest shown by the BBC, and as such I received key support for an in-the-wild deployment in a broadcast environment. StoryCrate was developed as a response to BBC's interest in driving creative practice within smaller (5-10 people) situated production teams. Described in detail in chapter 3, StoryCrate is a centralised collaborative, tangible, table-top interface providing a shared representation of a TV shoot to those in the production team situated on location. Tools are provided to the crew to facilitate awareness of the shoot, and a shared space around which to explore creative ideas collaboratively. StoryCrate was deployed over a 3 day shoot in-the-wild, Chapter 4 discusses this study and the implications therein for interaction design.

### *1.5.2 ProductionCrate*

Chapters 5 through 8 of this thesis describe **ProductionCrate**, a suite of technologies designed in response to the growing requirement for 'community of interest' events such as academic conferences to provide a rich integrated media experience to attendees. ProductionCrate's objective is to facilitate connections between attendees, creating common ground using event content and social media. A suite of attendee facing technologies presenting interactive and social media to attendees is backed by a distributed infrastructure of media management and routing technologies allowing media production tasks to be taken on by members of the event community. A centralized data management store provides content management capability to various mobile and tablet interfaces designed to create self-contained production workflows for individuals whilst simultaneously allowing them to participate in the event.

## 1.6 Principle Contributions

This thesis presents the design and implementation of two large scale production systems deployed in two situated media production environments. These designs open a discussion into where new interactive technologies can fit into environments that share similar situational factors to situated media production, in order to improve the production workflows for these situated teams. Through discussing the real world deployments of these interfaces, I present a set of design considerations for collaborative interaction technologies to improve situated media production. I further envisage the manner in which these designs might apply across other production scenarios which share common situational factors.

As a secondary contribution, implicitly I present insights and an understanding of these complex situational domains through the design and deployment of new technologies, highlighting the effect that situational factors have on other media production domains and collaborative technology practice.

## 1.7 Action Research

My experience from 10 years of working in and managing situated production teams gives me key insights into the common working practices and situational factors faced by production teams. This experiential knowledge and my continued participation within the production domain has facilitated the development of collaborative technology which legitimately considers situational factors for design, and is driven by personal insights into how production teams might appropriate and assimilate any new technologies into their workflows. Both the StoryCrate and ProductionCrate case studies subscribe to the 'making by doing' practical approach to research advocated by Action Research (AR), as summarised by (Hayes, 2011). AR describes a model for deploying technological (physical) interventions into inter-disciplinary real-world environments to systematically promote sustainable change within those environments. By employing an AR approach to each situated production scenario, and by leveraging my own status as having a legitimate background in production environments, I deployed both StoryCrate and ProductionCrate as interventions into in-the-wild (Johnson & Rogers, 2012) production scenarios. Through these interventions I could observe, and subsequently discuss the impact of these technologies on the workflow and collaboration between team members to gauge impact and improvement over the existing workflow. Hayes exhorts AR as a pragmatic yet user centred approach which reveals situation-specific results and is involved in the community in question:

*"AR research focuses on highly contextualized, localized solutions with a greater emphasis on transferability than generalizability"*

Indeed, the relevant stakeholder communities (BBC, HCI community) for each project became key partners in defining the scope and target production scenarios for each deployment, and led the commissioning of appropriate situated events into which the resulting technologies were deployed and evaluated. In each case, participants from both the production domain and the research community participated in the creation and analysis of the observational strategies employed with the intention of transferring the results into future projects in their own organisations. To develop technologies which would stand up to use in-the-wild, I approached the design phase of AR as an autobiographical design (Neustaedter & Sengers, 2012) exercise, at key stages returning these designs to the relevant stakeholders for validation.

## 1.8 Thesis Outline

This thesis is split into four primary sections, Chapters 1 and 2 introduce the reader to the concepts and challenges surrounding situated media production, and explores existing research and supporting work related to these domains, focussing on the opportunities that are presented by new forms of interaction technology for augmenting the collaborative production workflow. A discussion on interaction technology available for situated media production is supported by examples of how these technologies have previously been deployed in collaborative scenarios that share factors with media production. Chapters 3 and 4 report on the design, deployment and analysis of StoryCrate, framing design decisions, describing the physical and software characteristics and subsequently providing an analysis of an in-the-wild deployment of the system. Chapters 5, 6 and 7 are structured similarly, reporting on the ProductionCrate system. Chapter 5 introduces underlying design concepts and supporting technology for the system. Chapter 6 reports on the elements of ProductionCrate targeted at producing and curating and managing media, discussing in detail design decisions impacting on the collaborative production workflow in a non-professional environment. Concluding this case study, Chapter 7 provides an account of two large deployments of ProductionCrate in 'community of interest' event settings, and discusses the implications and lessons for designing collaborative production technology gained from these deployments. Chapter 8 concludes the thesis with a discussion capturing key design considerations and interaction nuances across the two previous case studies. It is here I make clear links between the situational factors discussed in this chapter and the deployments described and observed in Chapters 3 through 7. Closing this chapter I present clear implications for designing and deploying collaborative interaction technologies within situated collaborative media production, and highlight opportunities for future work.

# Chapter 2. Background Literature

Computer Supported Cooperative Work (CSCW), a term first coined by Greif and Cashman in 1984, provides frameworks for understanding team based environments and methods for designing technology tools to facilitate group work. Nearly 30 years of CSCW research, initially addressing work settings but subsequently expanding to consider education, families and social settings, has led to a wide range of interaction techniques, technologies and systems being proposed for collaborating groups of users. This legacy of CSCW research has an important bearing on both StoryCrate and ProductionCrate in relation to the system concepts, specific interaction techniques proposed, and my approach to evaluating co-located collaborative situated media production. In this chapter I present a broad review of table-top, tangible and mixed-mode interaction technology, highlighting key affordances that support team based interaction in situated media production scenarios. This review covers only the key areas that are relevant to the situated factors described in Chapter 1, discussing the areas of previous work relevant to these issues.

## 2.1 Computer Supported Cooperative Work

A core concern of CSCW research is the development of understandings of team dynamics and technology affordances in complex collaborative situations. Through observation and evaluation of deployments in many diverse settings, CSCW has been distinctive in its identification of the importance of environmental and relational complexities that impact on the effectiveness of cooperative work performed by teams. The impact and significance of factors such as power dynamics, individual role perception, stakeholder roles and multi-skilling, have been well documented especially within workplace settings (Linde, 1988). Through examinations of specific collaborative scenarios CSCW has revealed the contextual factors associated with team working in a variety of domains and proposed technology interventions that facilitate workflows given these constraints and affordances of the specific settings. This contextual underpinning is the key to understanding both individual and team roles and thus the models developed to understand these situations depend on an appreciation of the context in which technology is deployed. Understanding these situational factors, the team and the impact of technology on the workflow has been addressed by both multi-faceted approaches (Neale, Carroll, & Rosson, 2004), where observation is led by the situation, and targeted laboratory investigations (Convertino, Neale, Hobby, Carroll, & Rosson, 2004), where situational factors are tightly controlled, and while both approaches have proved effective for these complex scenarios, both are themselves contextually dependent (on the situations they were developed to analyse).

*Table 1 The CSCW Matrix (Baecker 1995)*

| | **Same Time** | **Different Time** |
|---|---|---|
| **Same Place** | 1 | 2 |
| **Different Place** | 3 | 4 |

The standard matrix (Table 1) of temporal and spatial categories introduced by Johansen (1988), and later by Baecker *et al.* (Baecker, 1995) still provides a useful distinction between the settings and constraints in which collaborative work is undertaken. Here the primary use cases, for situated media production, can broadly be considered same-time-same-place collaborations (1), although the realities and complexities of production scenarios mean that predominantly collocated collaboration may at times be dislocated (e.g. where there are multiple venues, or simultaneous production shoots are used). Indeed, this is well understood in previous CSCW research, for example, work with SWAT teams (Jones & Hinds, 2002) described teams can be a mix of distributed and co-located highly skilled workers within a very confined time window working in unknown places with varied timescales. Likewise, the teams introduced in Chapter 1 work within structured time boundaries within a small physical area, but in TV production I observe a temporal dislocation between actual film crews and post-production teams (the composition of which may overlap). Similarly, for a live conference event, while the primary focus of work is within the same physical location (such as a conference centre), in practice this may comprise multiple sub-venues, each of which is physically large and present individual workflow constraints. Furthermore, in both settings some preparatory “work” is done in the period preceding the collaborative phase of the media production which impacts on the situated workflow.

## 2.2 Theories for Describing CSCW Scenarios

As both StoryCrate and ProductionCrate are CSCW interventions it is important to understand the theoretical models of team interaction through which such settings (and eventually the systems) can be described and analysed. Halverson lists numerous applicable theories but notes that there is no all-encompassing solution (Halverson, 2002). The two most commonly applied and developed approaches for modelling team behaviour and interactions; especially within the field of Human Computer Interaction are Distributed Cognition and Activity Theory. Halverson reasons that a useful and applicable theory fulfils four key roles: they reveal the truth (describing); they can be used to persuade others (rhetorical power); they can be used to predict the consequences of change in the domain (inference) and they lead to application of lessons gained from applying the theory (transferability). Both Distributed Cognition (DCog) and Activity Theory (AT) fulfil these criteria, offering valuable insights and a method of understanding group interaction in terms of users' cognitive experience. Therefore all understanding gained from these theories is based on understanding the observed cognitive features of the individuals within the team. Similarly, both theories are based on the gathering of ethnographic evidence from the targeted group workflow in context.

### *2.2.1 Activity Theory*

AT is a structured theoretical model that makes use of specific terms and constructs to describe how activities are accomplished by users (Kuutti, 1996). Practices (activities) are dependent on the environmental context, and can be split into a hierarchical model of actions that consist of a number of objectives. Accordingly, the unit of analysis in AT is the 'action' or 'activity' performed by an individual (or group of individuals) in response to their motivation. Contextual artefacts within the environment mediate the interaction between a user and their objective, driven by this motivation. The motive can be sub-divided into goals relating to each action and again into the conditions that govern their resulting interaction with artefacts. An interest in artefacts often forms the basis of AT's application in HCI, as artefacts provide the means and feedback through which users interact with each other and a system, and often translate technology interventions introduced by the researcher. Activities are initiated by a user, so AT is concerned with the motivation for performing the action and the resulting affectation they experience through using the artefact. Nardi *et al* have done much to allow AT to be applied to HCI by providing guidance in recognising the important actions, users and mediators in CSCW contexts (Nardi, 1996). During group interaction, artefacts often mediate between multiple users and their objectives, and the group often shares a higher-level motivation (related to the given activity). Each user's personal motivations have an effect on the group as a whole, so understanding the provenance of each user's individual activities is important in describing the group process. Each user's personal experience and contextual understanding is key to understanding their appropriation of artefacts and their personal motivations within AT, but due to the modelling of a group as separate individuals each performing sub-actions, it is more difficult using AT to gain insight into relationships between users that are not mediated through artefacts.

### *2.2.2 Distributed Cognition*

When compared to AT, DCog provides substantially less structure and fewer theoretical constructs for modelling group activities, and as a result can be just as difficult to apply appropriately to a scenario. DCog takes a systems approach to describing any scenario, modelling the information flow and cognitive processes during the performance of an activity (Y Rogers & Ellis, 1994). Users, artefacts and the environment are modelled as similar units of analysis within DCog; at any point in time, these units can represent a particular state, and subsequent processes can be performed on them to change their state in order to achieve a goal. State representations form the core of cognitive description of a system, such that a state may be in the user's mind, or visualised on a display or inside an object – DCog treats these identically. Similarly to AT, a user's past experience and skill level in manipulating a particular representation using artefacts directly affects their cognitive ability to transform a representation, but in DCog this is represented by efficiency in the information flow between the user and the artefact. DCog describes the overall system in social-technical terms, and maintains a commitment to understanding the broader socio-cultural context in which the system is operating. In contrast to AT, the relationships between units in the system in DCog are not implicit, and can be described and analysed as further items in the system. DCog recognizes the importance of a group of users transferring knowledge about state transformation as part of the process, and allows for the dynamic reconfiguring of users and tools within the system without changing the model. Wright *et al.* (Wright, Fields, & Harrison, 2000) identified the difficulties in applying traditional DCog in HCI, developing the 'resource model' of DCog to model familiar HCI tasks.

## 2.3 Core Design Considerations for CSCW

Through the application of AT and DCog by the CSCW research community, a set of core design considerations for collaborative interaction has emerged, including: providing ***mutual awareness***, providing ***flexibility*** through smaller building blocks of supporting functionality and supporting ***complex*** tasks and team structures (Carstensen & Schmidt, 1999). These considerations provide a starting point for exploring the design of tools to support situated media production teams in the context of CSCW. Previous HCI research has sought to address the design challenges raised by these key considerations by developing technologies and interaction techniques that facilitate group mediated interaction, but Ackerman argues that there is still an 'intellectual divide' between the key challenges in CSCW and the technology and tools available to support these workflows (Ackerman, 2000). Grudin *et al.* agree stating that the lack of transferrable interaction designs is a wider issue related to the contextual specificity of CSCW interfaces, and the difficulty in re-appropriating lessons learnt to other domains. The situational factors that impact team-based media production also impact a variety of other CSCW scenarios. These factors: team membership, professional considerations, technology, liveness, coordination and environmental factors, can be mapped onto the three core CSCW considerations to highlight key lessons for designing situated media production tools.

### *2.3.1 Mutual Awareness*

Mutual awareness within a team can be described as the level of knowledge that users have of other members of the team activities and states. There has been a historical tradition of focusing on spatial mutual awareness, and interfaces designed to promote spatial awareness of the team members themselves (i.e. their location and orientation). However, Rodden challenged this emphasis on mutual spatial awareness of users (as spatial entities), and proposed a more general model for the projection of other actions onto “a pool of shared objects” to promote mutual awareness of a wider range of factors (Rodden, 1996). Dourish & Bellotti (Dourish & Bellotti, 1992) outlined the advantages of mutual awareness in CSCW contexts, concluding that a system of ‘shared feedback’ (awareness) leads to: i) a reduced cognitive cost to each individual by allowing passive information collection; ii) users being able to extract whatever awareness information they feel relevant to their current activity and iii) in conjunction with a shared workspace, allows users to browse awareness information concurrently whilst performing other tasks. Berry *et al*. introduced the notion that although these shared representations can offer each user an identical representation of the group task, when performing actions within a shared workspace, representations tailored to specific users facilitates more efficient individual control (Berry, Bartram, & Booth, 2005). In response, he proposed that through a distribution of control throughout a cooperative system, the reduction of visual clutter and introduction of control policies associated with roles will reduce complexity of each individual’s tasks.

‘TeamTag’ (Morris & Paepcke, 2006) explored collaborative control distribution specifically, within a tangible interface context. In contrast with Berry *et al.*’s findings, TeamTag users expressed a preference for replicated controls in a shared workspace over distributed controls. In both these examples, role based control distribution and individual replicated controls support a more efficient individual workflow either by removing superfluous controls (in the former), or physically allowing for a shared workspace uncluttered with un-claimed controls (in the latter).

The analysis of SWAT teams by (Jones & Hinds, 2002) records that in environments where situational factors severely impact on the scenario outcome – such as coordination in life threatening situations --, small teams of highly skilled professionals can only accomplish the task through a network of constant communication. Jones highlights the importance of sharing critical context information with the team as well as clear communication lines, especially when the team is physically distributed. In moments where team members lost context information and communication, they perceived an in-ability to make decisions.

In Jones’ case, no technology was employed other than radios to support a shared state representation. In contrast, when the Bakerloo Line on the London Underground experienced a technology overhaul observed by Heath and Lough (Heath & Luff, 1990), they observed that alongside specific HCI technologies integrated in the workflow to support state awareness, the operations team depended on socially agreed workflows which augmented the technology to contextualise and monitor each other's actions. This technology supported an individual perception of team-membership, a key situational factor in such a socially driven context. Professional considerations can conflict with supporting complete mutual state awareness. Röcker and Magerkurth (Röcker & Magerkurth, 2007) propose that scenarios where individuals input creativly or intellectually, there exists a tradeoff between supporting total awarenss of each users' actions and supporting individual privacy and intellectual property. Additioanlly, systems with overwhelming mutual awarenss may produce unwanted interupttions to users reducing their ability to perform their individual roles.

### *2.3.2 Flexibility*

Flexibility within CSCW interfaces describes the affordances of an interface to support a flexible user workflow (moving between states or modes of a tool), either for an individual's interaction or by supporting flexibility in the team workflow, role and task distribution. Each member of the team is different so collaborative tools should support each users' individual approach to the task through the interface. In response to the challenges of designing interfaces for scenarios with environmental factors that encompass high cognitive load and noisy environments, such as emergency response control, Oviatt *et al.* (Oviatt, Coulston, & Lunsford, 2004) showed that multi-modal interfaces are inherently flexible (for single users) and decrease cognitive load for complex and responsive tasks. The multi-modal nature (pen and speech) of the emergency response control interface allowed users to dynamically re-appropriate software tools to match their personal working style in response to changing tasks.

Often a trade-off exists between the requirements for an interface that supports individual interaction (through expressive controls) and that which supports group interaction (through awareness of each-other and the tasks being performed across the team). Gutwin *et al.* (Gutwin & Greenberg, 1998) suggests that designers can understand this problem by considering three things: How additional views onto the shared workspace (possibly on a personal device) can be used; How individual actions are perceived by other group members; How the workspace is represented for each individual user on their interface. Gutwin does not propose a particular design solution but suggests that it is key to balance complex individual interaction and a shared workspace for the team through appropriate understanding of these three areas. In each of these topics, supporting a flexible workflow for each user and giving them control over their perceived representation and complexity of interaction allows them to engage with the group workflow in an individually appropriate way.

In many situated production scenarios, environmental factors considerably impact on the ability for the team to be mutually aware of each other's actions and on each individual user's capability to interact with specific equipment in the expected manner. When considering these contexts and the need to support multiple modes and interaction possibilities, Bødker's descriptions of the benefits of flexibility become apparent:

> *"Flexibility can mean that there are alternative ways for the user to achieve a certain goal and that a user can change [functions] to better suit his or her need"* - (Bødker, 1989)

Although Bødker is promoting the benefits of flexible designs for single user interfaces and not for complex environmental factors, he notes that individual flexibility is supported by concurrent and multi-modal mutual awareness, as Gutwin suggested. Reinhard (Reinhard, Schweitzer, Volksen, & Weber, 1994) uses flexibility as the key measure for evaluating his CSCW taxonomy. He distinguishes three types of flexibility that CSCW tools can support: Tools that support multiple applications (tasks) are better than single user ones, as multiple tools (and interactions) do not have to be learnt for each new task. In addition, a modular application design which does not cut off communication links or awareness when switching between tasks improves continued interaction and communication; CSCW interfaces should support flexible communication strategies between users both explicitly and implicitly, and interfaces should be open to new team members for rapid uptake; Supporting CSCW team communication through varied technology across the team, or when hardware is changing is important. Tasks may have to be performed on multiple different platforms or devices, and this must be supported so that tasks can be accomplished independent of specific hardware availability.

Teasley (Teasley, Covi, Krishnan, & Olson, 2000) describes a wave of interest in placing groups into 'war room' style situations to perform collaborative tasks, controlling the environment to make the team respond in a particular way. Environmental factors in many production scenarios prevent a physically centralised place for group work, but in fact, Teasly notes the 'war room' environment supports group work through constant mutual awareness and spontaneous communication. Viewed in these terms, offering flexible communication channels between users that can be appropriated in response to current tasks and tools that are flexible to the unexpected environmental factors that emerge is key to supporting a reflexive team.

### *2.3.3 Complexity*

Many of the situational factors that impact situated media production can be described in terms of the complexity that they introduce to team workflow and individual tasks. For example, complex technical equipment may need to be operated correctly, complex teams need to be coordinated in time-critical situations and individual roles can become more complex given particular environmental factors such as ambient noise level. From a study of a high complexity (and high stress) collaborative environment (police helicopter operations), Linde (Linde, 1988) reveals the complexity of inter-team power relationships in such critical situations and how they are affected by social, temporal and perceived authority levels. Although an extreme environment, this scenario demonstrates that even within clearly defined hierarchical CSCW scenarios, roles, expertise and leadership are all complex and changing phenomena. Schmidt's 'Remarks on the Complexity of Cooperative Work' (K. Schmidt, 2002) support these observations by declaring that defining complexity in a democratic scenario is just as complex, especially where situational factors aggregate to produce complex environments.

By highlighting failures in a variety of CSCW systems, Erickson (Erickson, 1989) demonstrated that even the simplest CSCW environments suffer from an inherent complexity. This complexity can lead to interruptions of an individual's workflow by other team members or by external factors. Speier (Speier, Vessey, & Valacich, 2003) proposes that if designed correctly, CSCW interfaces can mitigate the effect of interruptions by providing a fast recovery mechanism to bring the user back to their previous state of interaction. Further experiential work by Speier demonstrated that spatially based interfaces support a faster recovery from interruption, and that generally interruption when using smaller less-complex interfaces do not cause as much disruption to the user.

In 1995, Hopkin produced a detailed study of the human factors associated with air traffic control systems, particularly the understanding of complex coordination and liveness factors resulting in a high cognitive load. Since then, researchers have deployed technology interventions into this domain making use of a variety of interaction techniques (Hopkin, 1995). As new CSCW technologies emerged, each was deployed in air traffic control, with the understanding that this was the epitome of an environment that was significantly impacted by environmental, coordination, liveness and professional situational factors in which to 'soak test' new interaction technologies. Digital pens (Chatty & Lecoanet, 1996), and later digital table-tops (Conversy et al., 2011) have been deployed to enable the recording of actions within air traffic control, and to build in extra functionality into workflows that were already established (such as paper-based flight routing). These technologies successfully supported coordination amongst the team by replicating existing physical representations with digitally augmented physical representations using table-tops and pens.

## 2.4 Technologies for Situated Collaborative Interaction

Although there is a long history of developing new user interface technologies for CSCW, recent developments in low-cost touch-enabled display technologies such as multi-touch table-tops (Mueller-Tomfelde, 2010) and 3D tracking (Izadi et al., 2011) have significantly expanded the possibilities for collocated interaction design in particular. Likewise, recent developments in cheaper, more powerful mobile and tablet devices have opened up possibilities for integrating personal and group based interaction to create more complex and individually responsive collaborative tools.

Keeping in mind the CSCW scenarios introduced so far, in this section I categorize relevant technologies into three categories: Table-top interaction, Graspable and Tangible Interaction and Personal Mobile Device Interaction. For each I describe the key technical features of the technology and canonical example implementations.

While not all those included have been developed for collaborative interfaces specifically, each presents key affordances for group or individual interaction given the situational factors introduced in Chapter 1.

### *2.4.1 Table-Top Interaction*

In the early nineties Wellner became intrigued by the particular affordances of paper that rendered it so effective compared to digital alternatives (Wellner, 1993). Physical properties such as thickness, weight, porosity, transparency, and flexibility afford actions such as grasping, carrying, folding, and writing which are not inherently supported by digital solutions (Sellen & Harper, 2003). Rather than continue the search for suitable (digital) replacements for paper, he instead turned to the challenge of augmenting the physical surface on which paper is used, the table-top. His 'DigitalDesk' presented the user with a physical desk augmented with a projected display and cameras for tracking interactions with objects on the desk surface. Users could use the desk as normal, with paper and pens while the DigitalDesk tracks finger, paper and object interactions, responding with augmented visual feedback. Although DigitalDesk investigated many of the issues surrounding the augmentation of table-tops with digital content, it was designed primarily for use in individual work contexts. Since the DigitalDesk, interest in table-top interaction design and research has grown rapidly, and the affordances of table-tops for multi-user interaction are now well understood, as described succinctly by Shen (C. Shen, 2007):

> *"[A table-top] affords and encourages collaboration, coordination, serendipity, as well as simultaneous and parallel interaction among multiple people." - Shen*

Although digital table-tops are known to promote and support collaborative interaction, Scott *et al*.'s (S. D. Scott, Grant, & Mandryk, 2003) extensively cited guide for collaborative table-top design identifies five key affordances that digital augmented table-tops must possess to be effective in a group environment: natural interpersonal interaction; transitions between personal and group work; transitions between table-top collaboration and external work; flexible user arrangements; and simultaneous user interactions.

By viewing table-top interaction in terms of affordances that support sharing, designs can be described by two key aspects, ***entry*** and ***access*** (E Hornecker, Marshall, &

Rogers, 2007). ***Entry*** regards the process through which a potential user is introduced to the interface (table), including its observe-ability (and the increasing familiarity with interaction techniques and metaphors through the observation of others), and the social effect of seeing others successfully using an interface. On larger table-tops that dominate a specific location, it is key that the interface draws people into interaction with it. Once engaged, support to fluidly share data with other users and the number and type of available input opportunities is an important measure of share-ability. ***Access*** refers to the characteristics of an interface that support users actually doing things or perform actions. Hornecker describes how entry points support users getting to access points, with entry guiding users towards (multiple) opportunities for access. Successful provision of these two affordances gives table-top interfaces the potential to engage users without prior knowledge or intention of engaging.

As highlighted by Sellen, Digital table-top interfaces do not provide the same physical affordances as paper documents, and in particular the notion of a unique and individual document. Paper inherently supports privacy, non-duplication and requires social communication protocols for sharing within a group. When replicating these properties in the digital space, it is key to provide methods of conflict resolution and inter-personal coordination which are not inherently afforded by the physical properties of the interface (Morris, Cassanego, & Paepcke, 2006). Morris demonstrates how it is vital to maintain a clear and predictable strategy in the interface for conflict management to support these situations. Often this may be not moving a digital item if two users are dragging it towards each-other on the table-top, but a digital surfaces provide the opportunity for paradigms that paper does not, such as duplicating an item, or splitting it in half when conflict occurs.

Traditional paper based work support mediation between group and personal work through physical properties of the paper (ability to hold away from other users and work away from the table) and of the group workspace (size of the table supporting private areas). In digitally augmented systems however, the notion of private and public space is limited as all data is confined to within the table-top display area in a particular orientation (flat). Specific implementations of privacy technology have been introduced, such as polarised filters, to bring elements of privacy back to table-top interfaces (R. T. Smith & Piekarski, 2008), but these require users to be at specific (and sometimes fixed) positions around the workspace. Scott's (S. D. S. Scott, Sheelagh, Carpendale, & Inkpen, 2004) continued research into territoriality in table-top groupware encourages interface designers to consider both the spatial and functional allowances given to areas of the interface, enabling space to be appropriated for personal or shared use. He presents three key areas of territory that emerge in table-top interaction: group, personal and storage. Studies performed using these constructs suggest that facilitating a user fluidly interacting across all three of these types of areas supports group interaction.

Stewart *et al*.'s (Stewart, Bederson, & Druin, 1999) work on single display groupware highlights the benefits of providing a single focal point for group work (the display). A singular display provides both a shared display area and interaction space which all users are directly aware of. Conversely, he warns of a potential design problem: that users may actually collaborate less given a single point of interaction. That is, since users can act on their own (and all their actions are visible), there may be no imperative to communicate with others in order to complete a task. Additionally, social structure in cooperative rather than collaborative situations such as emerging leadership or strong personalities in the group may divert the entire group away from the required task. This analysis presumes a larger task can split into discrete sub-tasks, each allocated to individuals, but in situated production teams, this is often not possible. In a production scenario producing a singular coordinated output, individual tasks are inter-dependent on coordinated action from multiple members of the team.

The physical size and large surface area of a table presents clear affordances for spatial representation and interaction. Studies by Chun *et al.* (Chun & Jiang, 1998) demonstrate that users create a specific spatial memory of objects and their positional relationships which provide contextual cueing (the learnt spatial arrangement of objects) that enhances memory recall of the interaction scenario. Similarly, Russell *et al*. (Russell, Drews, & Sue, 2002) describes how large, multi-user displays can scaffold users' understanding and manipulation of concepts within group work and Elrod (Elrod et al., 1992) describes how electronic whiteboards deployed in group presentation scenarios encouraged a wider audience to participate in discussion due to a shared single point of reference that all users could see. Current technology now combines high-resolution, large form factor displays with multi-touch, 3D and physical tracking technologies to create large collaborative interfaces for complex information, but appropriating these technologies for interfaces with multiple users still presents key issues for interaction design.

In their discussion of large display groupware, Swaminathan *et al.* (Swaminathan & Sato, 1997) proposes that the readability of a large display is based on the distance it is viewed from as well as the resolution, a fact not widely considered in interface design until shared co-located groupware emerged. Their empirical studies also highlighted that direct manipulation is key when interacting with large displays due to the counter-intuitive nature of non-linear interaction mapping (as with a mouse). On comparing non-direct (mouse) and direct (touch) interaction, Forlines *et al.* (Forlines, Wigdor, Shen, & Balakrishnan, 2007) proposed that touch was beneficial over use of a mouse in bi-manual interaction, and that while direct-touch interaction is neither faster or more accurate, it affords spatial recall and group awareness in multi-user scenarios. Chan *et al.* (Chan et al., 2010) supported this notion by showing that direct touch interaction improves 3D manipulation of objects on a touch interface when compared to non-direct methods. To allow multiple users direct manipulation on a table-top interface, they must be able to perform complex interactions both individually and simultaneously. Multi-touch technology has emerged as one solution to this problem, allowing multiple users, with multiple fingers to perform direct manipulation of interface elements.

### Technologies

In 2001, researchers at MERL presented their DiamondTouch technology which allowed up to four users simultaneously to touch a front projected table-top display for direct interaction (Dietz & Leigh, 2001). This technology is limited to front projection, a specific table size and a maximum number of users, who have to be situated on a connected pad (either on a chair or on the floor), and these constraints would prevent use in group scenarios that are significantly impacted by space constraints and lighting conditions. Since DiamondTouch, numerous technologies have emerged for implementing interactive table-top interfaces with (multiple) input capability, broadly falling into three categories: optical, electronic and audio based sensing.

***Optical*** In 2005 Jeff Han (Han, 2005) introduced a simple and effective method of building optical multi-touch displays, based on the principle of Frustrated Total Internal Reflection (FTIR). Using an off-the-shelf camera and infrared LED's, developers and researchers were able build a multi-user interactive display for little effort or cost. Indeed, FTIR sparked a revival in interactive table-top research, allowing many more researchers to use multi-touch (and therefore multi-user table-tops) as a facilitating technology for CSCW settings. Many variations of camera-based tracking have been explored, including Laser Light Planes (Park & Han, 2010), ink displacement displays (Hilliges, Kim, & Izadi, 2008), and Diffuse Illumination (Mueller-Tomfelde, 2010). After FTIR, Diffuse Illumination (DI) is the most commonly implemented technology for interactive displays, again due to its low cost and that tangible objects can be tracked using fiducial markers or other similarly robust approaches. The ReacTable music interface (Kaltenbrunner & Bencina, 2007), was one of the most notable DI tablet-top systems and used large amounts of emitted infrared light, which reflects off any reflective material placed on the surface of the table. Software is used to track specifically calibrated areas of pixels, such as fingers or markers. More recently, technology developments have led to a hybrid form of optical sensing consisting of a traditional LCD display augmented with extra 'sensing' pixels (Microsoft, 2012), initially demonstrated in 'ThinSight' (Hodges, Izadi, Butler, Rrustemi, & Buxton, 2007). These devices operate much the same as a very large un-focussed camera at a similar resolution to the display output.

***Electronic*** Of the non-optical sensing techniques, capacitive sensing of touch is the most widely utilized. Many commercial systems make use of capacitive multi-touch displays on mobile devices[11], tablet PCs[12] and personal computers[13], but only recently have these devices been available for larger installations such as table-tops. Although

[11] http://www.samsung.com/global/microsite/galaxys2/html/

[12] http://www.apple.com/uk/ipad/

[13] http://uk.asus.com/Allinone_PCs/

capacitive technology now allows for many touches (>20) (Baxter, 1996), limited size and form factor configurations are available for use in custom deployments. Ferro-magnetic (Hook, Taylor, Butler, Villar, & Izadi, 2009) and electro-sonic (Kurata, Oyabu, & Sakata, 2005) technologies for (multi-)touch interaction are also available and although they provide a new form of interaction, the commercial applications for such approaches are not well established and such systems have not progressed beyond research prototypes.

***Acoustic*** Acoustic sensing systems using piezo based foils (Rendl et al., 2012), or time-of-flight ultrasound sensors mounted around an interaction surface (Liu, Nikolovski, Mechbal, Hafez, & Vergé, 2010) have been presented as viable alternatives to optical and electronic touch sensing, but offer no clear cost or implementation advantages for typical display scenarios as they require technology to be mounted across or around the interaction area. Harrison (C. Harrison & Hudson, 2008) experiments with appropriating any material surface (size, shape or texture) for interaction by detecting the sound of user's scratching, using trained data sets to match against known gestures, but supports only a small and specific gesture set. Similarly, researchers have augmented electronic and optical touch sensing systems with acoustic sensing (Lopes, Jota, & Jorge, 2011) to gain more detailed and contextual information about user touch events, but these techniques are limited in the environmental conditions in which they can be deployed.

### Design Challenges

Table-top sensing and display technologies have a number of obvious applications to multi-user and collaborative interaction, but they also give rise to new design challenges. In particular, the environmental factors in team-based media production have a significant bearing on my selection of sensing and display technology, for example, in live production environments, technologies such as optical sensing may not lend themselves particularly to environments with rapidly changing lighting conditions (e.g. live music events) and capacitive sensing could be used to overcome lighting conditions, but may be hindered by operators wearing safety equipment such as gloves when operating equipment.

***Occlusion, Orientation and Text Entry*** The nature of a large display necessitates reaching behaviour across the surface to interact with distant elements of the interface. As well as providing an interaction design challenge (Shoemaker, Tang, & Booth, 2007), the act of reaching occludes the interface that is beneath the hand or arm. Various methods have been proposed to combat this, many of which rely on detecting the orientation of the user (F. Wang, Cao, Ren, & Irani, 2009), using this information to manipulate the interface accordingly so that it can still be seen by the user. Since users could approach a table from any direction, interface elements needs to be useable, or at least accessible (for subsequent moving), from any approach vector. Design responses have included the detection of user location and automated re-orientation of relevant menus, for example, around a circular display (Vernier, Lesh, & Shen, 2002). These issues are particularly relevant when considering text on a multi-user display. Text remains an essential element of information presentation, and techniques for optimising text readability and orientation remain an active area of research (D Wigdor & Balakrishnan, 2005). Text entry is accordingly an important factor in table-top interface design and many approaches have been proposed ranging from touchscreen keyboards (Findlater & Wobbrock, 2012), wireless keyboards (Kristensson et al., 2012), personal mobile devices (McAdam & Brewster, 2009) and hybrid pen-based keyboards (Kharrufa, Olivier, & Heslop, 2009). These approaches can be broadly distinguished according to the extent that they trade-off ease of entry with level of integration of the entry mechanism with the other interface elements.

***Identification and Privacy*** Identification of users interacting with an interface is an important factor to consider, especially within highly coordinated environments such as situated media production with complex team structures and user specific tasks to perform. Identification can be key for action logging, enforcing power control structures or for multi-use devices where customisation of complex UI's is key for rapid user switching.

Two distinct types of identification can be distinguished: true identification of specific users, and contextual identification of users within the interaction context which does not specific user data (such as what orientation an interaction occurs from). DiamondTouch supported both, but subsequent table-top technology dropped user identification as it was considered superfluous. In recent table-top application development, the lack of user identification is now recognised as a limitation of current technology. Subsequently many user identification solutions have been proposed for distinguishing users via other characteristics, including, individual gestures and mobile devices (Ramakers, Vanacken, Luyten, Coninx, & Schöning, 2012), shadow tracking (Segen & Kumar, 1999) and augmented camera equipment (Daniel Wigdor et al., 2009) but few solutions exist for native user identification.

By introducing the possibility of user identification, user privacy (and associated data privacy) is a design factor that warrants consideration. Some interfaces may require private interaction areas on a larger surface or specific authentication for initial access. It is possible to use special lenses placed on the surface of the display to prevent visibility of particular areas of the screen to multiple users (Möllers et al., 2011), or implementing hand gestures that physically prevent other users from seeing content (Wu & Balakrishnan, 2003). Alternatively, individual mobile devices could be used as external 'personal' display devices to display private content (McAdam & Brewster, 2011). For authenticating users on large multi-touch displays, Kim *et al.* (Kim et al., 2010) experimented with using of the subtle interaction affordances of multi-touch technology to allow password input in plain view of observers, but these interactions are dependent on particular types of multi-touch technology and users learning specific touch-based authentication methods. Personal mobile devices could also be used to authenticate, either by performing an authentication routine on the device or by physical presence at the large display (Ackad, Clayphan, Maldonado, & Kay, 2012).

***Physicality*** When using direct-interaction techniques (such as touch) to manipulate a table-top interface, a dichotomy exists between the expectation of a physical sensation from the user (as afforded by real objects on a real table), and the actual digital effect of their action. To re-unite the expected sensation to the experienced interaction, physical constructs (Newtonian physics) were brought into table-top application development (Agarawala & Balakrishnan, 2006) to give physical contextual feedback for direct manipulation. Rather than create a world of pseudo physical rules, some interfaces were created to entirely replicate an environment and the laws of physics that are naturally observable by users, such as 'PhysicsSynth', a multi-touch music creation tool which uses physics primitives in a pseudo physics environment to produce trigger signals for synthesizers (Hook et al., 2009). Designers are now replicating entire real world environments such as sandy beaches, aimed to digitise the physical affordances that make these environments so unique (such as sand) (Kazi, Chua, Zhao, Davis, & Low, 2011). By creating a tangible table-top interaction that acts more like a pile of loose objects, 'TurtleDove' attempts to bridge this gap between the real world physics of small item sorting, and the digital real of the table-top (Metz & Leichsenring, 2012), and by creating many small tangibles that can be physically manipulated like piles of 'stuff', actions such as sorting and grouping are afforded naturally. As the sensitivity of touch technology has improved, the inherent tactile response from an interaction (such as 'pressing' the screen for touch) has become ambiguous, especially when performing complex multi-fingered gestures. Finger trails are a solution introduced to provide users with a temporal and spatial indication of their current interaction in order to both improve their accuracy and remove ambiguity (Daniel Wigdor et al., 2009), and a pseudo projection of the users hand shadow on the interface have proved effective in helping users maintain context of their actions in digital space (Chan et al., 2010).

### *2.4.2 Graspable and Tangible Interaction*

The use of supplementary physical tools or objects for interaction holds significant potential to enhance collaborative user experience through leveraging users' skill in manipulating tactile artefacts. Although free-space manipulation of augmented objects has been demonstrated, table-tops offer particular physical properties that afford interaction with physical tools, specifically the ability to freely arrange and manipulate objects on the table surface, and as such, much research into 'tangible' interaction is based on table-top interfaces.

Tangible interfaces have been proposed in a multitude of form factors and using a wide range of remote and embedded sensing and display technologies, but the key affordances of physical interaction identified by in 'How Bodies Matter' (Klemmer, Hartmann, & Takayama, 2006) still hold true. He identifies five key themes related to the embodiment of actions that tangible interaction facilitates within a group context: i) thinking through doing, ii) performance, iii) visibility, iv) risk, and v) thick practice.

Tangible and physical interaction with objects encourages the user think about the result of their task, both through the embodiment of the action they are performing and through the use of movement related areas of their brain. Tangible interfaces facilitate rapid learning of actions and afford an inherent knowledge of the task being performed through the physical movements used. They allow users to understand the underlying tasks they are performing more easily through the way in which they perform them. Professionals in situated media production rely on their experience, taught skills and their tacit knowledge of the equipment and workflows that are required for their roles (Eraut, 2000), and build up tacit knowledge of the physical tools and actions that should be performed in response to situational tasks. Tangible interfaces can be designed to exploit this existing tacit knowledge to support production-like tasks and when supported by motor-memory based on experience of use, they can offer potentially faster more efficient interaction for experienced operators.

Combining the key affordances of visibility and performance, Hornecker *et al*. (E Hornecker, 2002) demonstrated that graspable interfaces resolve interaction ambiguities, embody actions visibly for communication partners and maintain a performative meaning during manipulation which enhances task understanding and shared experience amongst a group of users. This notion of embodied actions being visible to others is supported by implementations of multi-user games that make use of tangibles to facilitate collocated collaboration (Speelpenning, Antle, Doering, & van den Hoven, 2011), and the use of tangibles in remote collaboration scenarios such as remote desktops (Brave, Ishii, & Dahley, 1998).

Studies such as those carried out by Waldner *et al.* (Waldner, Hauber, Zauner, Haller, & Billinghurst, 2006) similarly demonstrated that tangible interaction provides affordances for collaborative work through action visibility and through the affordances revealed through the size and form of the tangible tools. Visibility is also closely related to the design goal of externalising a user's thinking (and related actions), which can promote peripheral awareness amongst the team of a user's intent and motivation. These affordances are demonstrated by Kusunoki *et al.* (Kusunoki, Sugimoto, & Hashizume, 1999) with a tangible board game for group space planning in which team member's work together to plan an office space with their own individual aims. Further research by Hornecker *et al.* (Eva Hornecker, 2005) describes how tangible systems provide a physical and virtual space in which to facilitate collaboration, and these spaces can specifically designed to encourage particular types of team interaction, and hinder others. Ishii & Ullmer's (Ishii & Ullmer, 1997) seminal 'Tangible Bits' work clearly sign-posted their vision of the benefits of peripheral communication channels in collaborative interfaces, and this concept has expanded on by many in subsequent designs of collaborative tangible interfaces (Eva Hornecker & Buur, 2006).

Bi-manual control is an example of 'thick practice' highlighted by Buxton (Buxton, 2008) as being cognitively advantageous for complex interaction scenarios, especially when appropriating physical tools to perform tasks. Although bi-manual (with hands and fingers) interaction is possible with multi-touch technology, two-handed interaction is more difficult to teach users due to the lack of kinaesthetic physical features within the interface to use as interaction reference points, with the result that the user is required to observe the display during the interaction. Tangibles afford control without direct eye contact with the interface device, and this can be particularly advantageous for the control of environmental variables that reside in the world beyond the interface itself, such as lighting in a theatre or other live production venue. Physical form and size for these tangible tools are key to providing users with the affordance for interaction when they will be relying on kinaesthetic feedback for their frame of reference, especially when the user will not be able to see the interaction tool (Hachet, Pouderoux, Guitton, & Gonzato, 2005). Similarly, Klemmer *et al*.'s concept of risk and personal responsibility comes into play here, as performing a physical action such as turning a dial or pushing a slider requires definite intent on the part of the user, resulting in an action that is observable by co-located users. Tangible interaction objects are often used in imaginative and unique ways but each instance can be classified into one of two broad categories:

i) Using tangible objects as tools or functions: Tanenbaum *et al.* (Tanenbaum & Antle, 2008) suggested that the ability to map physical constraints of digital functions onto inherent properties of physical objects allows interaction designers to build interfaces that themselves embody interaction constraints. Similarly, Ullmer *et al.* (B Ullmer, Ishii, & Jacob, 2005) observed that physical interactions can benefit from constraints on the environment in which they are being used to guide users in their interactions.

ii) Tangibles representing information or data: MediaBlocks (Brygg Ullmer, Ishii, & Glas, 1998), an early example of a tangible interface, uses physical metaphors of both controls and data containers to represent digital constructs physically. Terrenghi *et al.* (Terrenghi, Kirk, Sellen, & Izadi, 2007). then suggests that representing data physically presents advantages over a purely digital representation in when manipulating media items due to the physical affordances that support media related functions (such as search or sorting).

## Technologies

Tangible interaction necessitates the tracking of physical objects and their response to human stimulus. The possible interaction area is often confined, such as by table-top size, distance to a shared display or constraints of the object. As such, technologies have emerged to support a variety of possible dimensions when tracking such objects, broadly in three categories: 2D (table-top), 2.5D (table-top with limited depth) and 3D tracking:

***2D Space*** Tracking objects placed and manipulated on a table-top interaction space allows visual feedback to be displayed alongside the object when appropriate, whilst also supporting eyes-free interaction. The table-top surface provides a simple shared frame of reference for interaction with the objects, and position, orientation and presence of objects can be mapped to functions. Table-based tracking of tangible objects is most commonly implemented with optical tracking technology (similar to multi-touch technologies), such as that used in ReacTiVision (Bencina, Kaltenbrunner, & Jorda, 2005), and table-top tangible audio multi-user synthesizer. These systems use a live camera image of the interaction space, tracking identifiable (and unique) visual markers placed on tangible objects using visual segmentation of the filtered and background sub-tracked image. The position, orientation and existence of these patterns (and therefore objects), once processed through a calibration homography algorithm is determined from this image processing, resulting in software events. Both active (Hosokawa, Takeda, Shioiri, & Hirano, 2008) and passive (Jacko, 2009) RFID based methods of tracking have been proposed, by including an RFID tag inside each tangible object. Passive systems cannot easily identify the location or orientation of tags within a given space (only the presence) but do not require batteries or electronics mounted within the tangible, whereas active systems use triangulation of active radio (RFID) signals (Kurata et al., 2005) to obtain the position of the object on the table surface but may need regular charging.

Due to the commercial availability of capacitive multi-touch displays (and table-tops), tangible tracking systems have been developed that detect physical objects using either capacitive finger-like materials or capacitive modulation circuits inside the object which mimic the interaction with multiple fingers (Yu, Huang, et al., 2011). The relative combination or frequency at which these 'fingers' are located and their position within the display space provides information on the identity, orientation and type of the object being manipulated. Such solutions provide fast and accurate tracking of multiple objects but are limited by the maximum number of touch points available to be tracked on a capacitive display, often around 15. 'SLAP' Widgets (Weiss, Wagner, Jansen, & Jennings, 2009) is a hybrid tangible system for optically based multi-touch which use silicone based markers that 'pretend' to be particular finger combinations placed on the surface of the display and detected as markers. These objects have the advantage over solid tangibles as they support touch interaction 'through' their surface for example when using the SLAP keyboard (a silicone keyboard with visual and tactile feedback of key presses.

***2.5D Space*** Manipulation of objects on a flat surface limits to possible ways that objects can be mapped to tools and data within an interface. Common manipulations afforded by physical objects such as stacking and 3D spatial arrangement of items may be required, and software tools that map to more than rotate and translate operations may be available. 2.5D tracking systems are able to track additional interaction information about physical objects above a table-top interaction area, whilst maintaining the table-top as a shared frame of physical reference.

Techniques such as 'Lumino' (Baudisch, Becker, & Rudeck, 2010) and 'Stacks on the Surface' (Bartindale & Harrison, 2009) make use of structured transparency within each tangible placed on an optical tracking system (such as Diffuse Illumination) to detect piles of tangible objects. The order and presence of items in these stacks can be mapped to data organisation, process orders or used for reducing the amount of space used by objects on the table-top. For capacitive touch displays, Fujii (Fujii, Shimamura, Arakawa, & Arikawa, 2003) uses electronic pads located on the top and bottom of tangible objects which combine to produce unique combinations depending on stacking order.

Extra interaction opportunities can be supported by providing ‘active’ tangibles which contain specific interaction technology within the tangible, whilst being tracked using 2D tracking methods. Tangibles can be augmented with extra controls and feedback mechanisms specifically related to the function they perform or data they represent, such as those created by MacLean (MacLean, Snibbe, & Levin, 2000) using combinations of discrete and continuous electronic controls to produce complex physical interactions. They can also have autonomy when used away from the table-top interaction area (Merrill, Kalanithi, & Maes, 2007a) such as with ‘Siftables’, small display screens that can represent digital information away from a display, but act as tangible interaction objects when placed on a table-top. Interaction away from the table-top is recorded using electronic sensors such as accelerometers. Active tangibles can actuate in accordance with their role in the interface, such as with ‘Tangible Bots’, small motorised autonomous tangible objects that provide additional feedback to help and train users in interface tasks by moving around the table-top on small wheels (Pedersen & Hornbæk, 2011).

***3D Space*** Within the context of situated production scenarios with situational factors such as limited space availability, tracking physical objects in 3D space does not at first appear to be an appropriate technology to deploy. Conversely, media production crew are used to manipulating physical objects without the limitations set by table-top interfaces in their existing workflows, tools such as cameras, microphones and radios are devices with complex interaction possibilities but without the table-top based limitations of devices such as mixing desks. Few work-based collaborative scenarios have been proposed that offer interaction with physical objects in 3D space. Collaborative gaming comparatively has embraced 3D object manipulation, and devices such as the Nintendo Wii have demonstrated that 3D manipulation of objects does afford interaction possibilities for multiple users at the same display. In the case of the Wii Remote, multiple accelerometers and gyros act as an IMU which transmits it's attitude to the computation device via Bluetooth, but systems such as AR toolkit allow this tracking to be performed on simply graphical patterns printed on objects facing a camera (Fiala, 2005). These patterns are detected in a similar process to 2D table-top tracking, but output a 3D homography of the tracked object to the client software. With the recent availability of the Microsoft Kinect sensor, any environment can now be transformed into a tangible interaction space by 'scanning' the area to incrementally create a 3D model of the environment (Izadi et al., 2011). This process uses continuous volumetric integration of the depth steam to constantly refine a 6DOF 3D model of the surrounds. Any objects placed into this environment can then be independently tracked using the original environment geometry as a frame of reference.

### Design Challenges

Tangible interaction have been shown to support group work in collaborative scenarios and research has demonstrated the affordances for eyes-free and physical learnt interaction that would be beneficial to situated media production scenarios, but there exist some key design challenges in deploying these technologies to support this type of co-located team interaction in situated media scenarios. Hornecker highlights some key challenges to designing collocated tangible interaction: tangible manipulation & spatial interaction, embodied facilitation and expressive representation. These issues cut across domain boundaries, but are specifically pertinent questions when the interaction domain is impacted by the situational factors found in situated media production, as many of these factors impact on the physical, spatial and communication affordances of the interface.

***Tangible and Spatial Interaction*** The introduction of tangible and physical controls to an interaction space (such as a table-top) introduces challenges to designing appropriately responsive digital data representations. In a mapping application for example, tangible objects could be used to represent features on the landscape, but this removes the tacit digital ability to navigate around the map, as the tangible objects will instantly lose their contextual meaning as the map changes. In scenarios where the overall spatial representation can be fixed, such as the interactive city-wide game by Blast Theory (Koleva et al., 2001), based in a particular town, a digitally augmented table-top tangible system can be effective in maintaining a clear state of the interface, as the same real-world space is always represented by the same area on the table-top. Augmenting the physical objects to adjust their own position relative to the tablet-top has emerged as one solution to this problem of scaling a physically augmented digital world, and systems such as 'Tangible Bots' (Pedersen & Hornbæk, 2011) demonstrate the practical application of this type of responsive tangible interface which reflects changes to the digital representation by moving the tangible objects around on the table-top. The introduction of actuated tangibles has led to a growing interest in autonomous table-top tangibles which provide additional instruction or help to a user by autonomously performing tasks on the interface when not being manipulated by the user (Nowacka et al., 2013).

***Embodied Constraints*** The properties of tangible interaction tools can clearly embody digital constraints of an interface, for example dials that can turn in only one degree of freedom. Many digital interaction constructs such as buttons, sliders and dials can be tacitly translated to physical tools which embody the required constraints. For functions outside of this standard set however, there is currently no accepted rule-set for mapping tangible constraints to digital objects. This lack of existing mappings allows designers to devise more complex (and abstract) constraints but these must be balanced against the users' capabilities for learning new gestures.

Digital associations as well as functional constraints can be represented in physical form by using augmented tangibles. Audio and video feedback specific to the function a tangible performs can be displayed directly on the tool, such as the video on each video object in the 'Tangible Video Editor' (Zigelbaum, Horn, Shaer, & Jacob, 2007), preventing distraction of other users and presenting otherwise static data (e.g. thumbnails), dynamically (e.g. video). This augmentation of tangibles with digital information can be especially useful for complex control information specific to particular tools, such as those found in media production systems (e.g. optical settings relating to a particular camera). Haptic actuation of tangible tools can support multiple information channels for the users, and reveal constraints of the digital table-top environment to the users through touch and haptic feedback. The 'Tangible Table-top Puck' (Marquardt, 2009) clearly demonstrates this by actuating a brake and level on the tangible depending on the 'material' on the table-top underneath. Practical considerations such as the security and robust nature of the physical interaction tools are important environmental and deployment factors to consider when designing tools that rely on tangible interaction to operate correctly. Tools may be lost or broken, and as such systems need either to provide similar functionality through other means, or allow users to re-appropriate other physical tools to perform the same tasks. In situated media production environments, these tasks may be mission critical, and so strategies and procedures must be in place in case of loss or failure.

***Expressive Representation*** Tangible interaction supports representations of data and tools that embody features of the virtual in physical form to support more expressive interaction. Although this affordance of the physical is a clear advantage in many cases, a number of challenges emerge when designing for these types of interactions. In examples such as the 'ColorTable' (Maquil, Psik, & Wagner, 2008) a tool for supporting urban space planning for groups of professional urban planners and a variety of stakeholders , physical interaction is key to abstracting and communicating complex information to a collocated group. Tangible objects are used which model the scale, shape and relative physical properties of the various urban objects. Users could directly interact with the system by manipulating these physical features, adding new physical items to the digital space using a barcode scanner as a registration step. Although this interface supported the additional of new physical representations of data, these objects are of a known shape and size. Allowing the inclusion of arbitrary objects as representations for new data is a more complex design problem. As well as implementing tangible 'tiles' as tools in the interface, the entire projection surface was mounted on a rotating table which embodied the changing of the camera view in the planning application, combining the digital and physical representation seamlessly. During workshop use with this interface, it was discovered that the tangible objects needed to represent changeable attributes related to the tools they manifested, so rotating colour wheels (tangibles with physically changing attributed) were used as mode changers. Since this study, projects have been seeking usable ways of creating tangible controls which contain sub-attributes such as knobs or dials to provide additional inputs for user interaction. Many technical solutions now support this intricate tangible interaction, but when used on a table-top surface, the users' kinaesthetic ability to locate the controls is still hindered by the featureless table-top workspace. ColorTable offered physical representations of large scale structures that supported a reconfigurable digitally augmented planning interface for space planning. Previously, (Underkoffler & Ishii, 2002) had developed a town planning tool which was specifically designed for representing features of the planning environment that are difficult to model using a traditional table-top such as lighting, windows and weather. In this case, the physical representation of the buildings allowed users to both visually and physically see the issues affecting their planning decisions.

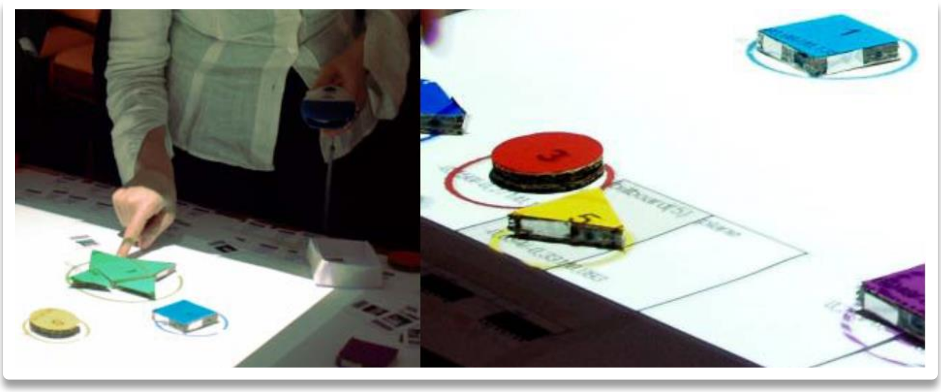

*Figure 3 The ColorTable – A System for Collaborative Urban Space Planning*

### 2.4.3 Personal Mobile Device Interaction

Many of us now interact with smaller, mobile computing devices such as mobile phones and tablets on a daily basis. This range of technologies open an array of possibilities for co-located collaborative interaction due to the rich interaction they afford for single users combined with the ability to easily share the device amongst a group. As I have highlighted, table-top interfaces are a useful interaction space for supporting co-located interaction. It is against this backdrop that mobile devices have been proposed as companion interaction systems that engage users in a variety of unique ways. The research community has investigated the affordances of mobile interaction devices in terms of locative interaction and pervasive technology. Within the context of CSCW however, I am primarily concerned with the properties of these devices that support co-located teams as personal interaction spaces.

***Personal Interaction Space*** Devices are now available that have high power processors, multi-touch screens, keyboards, large displays and multi-media capabilities alongside a multitude of environmental sensors such as GPS, accelerometers, light and compass. Mobile devices offer a powerful platform for user interaction especially as many users already understand how to operate their own mobile devices (phone, tablet, games console). Even intensive tasks such as video capture and editing can now be carried out directly on a mobile device, and users are able to upload directly to the internet (Jokela et al., 2007). Intricate interaction techniques such as text entry or drawing that are not well supported on table-top devices are common techniques of interacting with such mobile devices. Unlike larger devices such as laptops or desktop PCs, mobile devices are considered personal accessories which can represent traits of the owner (Häkkilä & Chatfield, 2006). Accordingly, users personalise the look and feel of their mobile device and the device software. This personalisation can lead to a user being able to perform tasks on their own device faster and more efficiently than on others. Due to the uptake of mobile devices that feature a multi-touch display, a set of common gestures have emerged for rich interaction with small displays that are now deployed on many mobile devices, for example devices are now expected to support 'Rotate, Scale, Transform' two-fingered gestures for common tasks such as image viewing or map navigation if they support multi-touch input. These socially accepted gestures can be used to create rich user interfaces quickly, and with few training requirements for new users.

Mobile devices support personal privacy and control over the visibility of the user's interaction and device content to other users in a group. The small form factor and hand-held capabilities allow users to move the device to face away from other users, or move themselves away from the group and still perform interactions on the device. The 'MobiComics' project makes good use of this affordance by facilitating users to create, share and edit comic strip tiles on their local device, whilst still participating in a wider group creative activity (Holopainen et al., 2011). Each user is able to control access to their own creative output through controlling the visibility of their device using existing social protocols (such as moving away from the group), or using their mobile device as a tool for indicating progress (such as holding it out for the group to see). By giving each user in a group their own mobile device, individual interaction with a shared workspace can be supported. Systems such as ‘Pebble’ (Myers, Stiel, & Gargiulo, 1998), allow interaction with a centralised digital workspace, in this case an electronic whiteboard, to be duplicated and shared amongst multiple users. Each mobile device allows a user to interact with the central interface independently using the affordances of a pen based mobile device, whilst providing and receiving live feedback from the group, and maintaining a large representation of the group’s progress on a shared display.

***Integrating Mobile with Large Displays*** Much previous work has demonstrated the potential of using personal mobile devices to provide expressive, intricate and complex user input to multiple users simultaneously in collaborative table-top scenarios. Although Forlines *et al.* (Forlines, Esenther, Shen, Wigdor, & Ryall, 2006) proposed splitting a table-top interface into distinct personal areas visibly marked on the surface, this solution still required users to be at a specific (and known) location around the interface. One alternative solution is to provide each user with an additional personal computing device (mobile device) on which to interact, whist using the larger table-top as a shared interface. As noted by Inkpen *et al*.’s (Inkpen, Hawkey, & Kellar, 2005) study into collocated collaborative technology configurations, it is important to understand that multiple smaller interaction spaces offer a more personal experience, and some users may prefer this, but for a number of people working together, designs must integrate both large and small displays into a cohesive interaction scenario which does not lock users into using just one of the technologies. In some cases such as in public interaction, a large display may not contain interaction technology, in which case smaller personal devices can be used as interaction portals to the larger space, such as controlling cursors in ‘ARC-Pad’, where user’s interact with their own mobile devices to accurately position a cursor on a larger shared display (McCallum & Irani, 2009). In cases where a large display does not exist at all, solutions by Kauko *et al.* (Kauko & Häkkilä, 2010), (Luyten, Verpoorten, & Coninx, 2007) and Schwarz *et al.* (Schwarz, Klionsky, Harrison, Dietz, & Wilson, 2012) can combine multiple co-located mobile devices into a larger displays by physically arranging devices next to each other to provide larger display and interaction spaces, as well as providing a reconfigurable and responsively shaped shared space. Conversely, the ‘MobiComics’ project, highlighted previously, uses the spatial arrangement of multiple mobile devices in front of a larger public display to allow a team of people to construct a comic strip. Tasks are distributed amongst the mobile devices on which comic strip tiles are created by individuals, and the larger display on which they are presented as a fully strip (Lucero, Holopainen, & Jokela, 2012), making use of both screen form factors to facilitate a shared task.

***Collocated Experience*** In recent years it has become socially acceptable to both use personal mobile devices within a group context and to share a device around a group to interact with specific content. Jacucci *et al.* (G Jacucci, Peltonen, & Morrison, 2010) describes this as the notion of 'active spectatorship', a quality of co-located mobile interaction that he has observed in a variety of informal collaborative mobile environments. The expressive actions of storytelling, joking and communicating presence are all observed in groups of users facilitated by personal mobile devices within informal settings, qualities only emerging through mobile interaction. 'Surprise Grabber' (Fan et al., 2011) is an example of a co-located social game where players use their mobile phones to 'catch' particular items in a virtual game environment by manipulating their mobile devices in free space in front of a large public display. The display visualises the shared game environment, while users manipulate their phones like a fishing rod to 'grab' items from the scene. The interface allows the use of a player's personal device as a controller and personal feedback device within a situated gameplay environment, making use of the rich interaction and hand-held affordances provided by the mobile device. Each personal device uses the built-in sensors in the devices as a rich input tool, which is only contextually meaningful when used in context with the group and large display, as the devices cannot be used without the larger display. In this case, mobile devices add personalisation, ownership and expressive interaction to a complex group scenario.

## Technologies

A multitude of complex and constantly evolving technologies are under development to support personal device interaction. Across these, three categories of technology have emerged as areas of consistent development and are key to understanding the capabilities of mobile devices in supporting new forms of user interaction and integration in collaborative technology scenarios.

***Sensing and Input*** In response to rapid advances in micro-electronics, manufacturers are provisioning mobile devices with a broad range of sensing equipment and input technology. In a survey conducted by Lane *et al* (Lane et al., 2010), the list of standard sensing components in mobile phones now includes: accelerometer, digital compass, gyroscope, GPS, microphone and multiple cameras. Augmenting this, some devices now include RFID, NFC, light sensors, temperature and humidity sensors and fingerprint readers. Additionally, many mobile devices now feature a multi-touch high resolution colour screen, which in most cases is capable of detecting multiple gestures and configurations of finger input. These technologies afford a vast array of interaction opportunities that can be developed using readily available consumer hardware in small, portable form factor packages. In addition, access to these sensors is through software interfaces, removing the requirement for complex hardware and electronic development expertise.

From the early examples of Personal Digital Assistants, pen based interaction has been a common input technique which affords natural and complex input of textual and drawn information and often includes hand-writing recognition. Technology for implementing pen based interaction on such small devices now includes: electromagnetic field detection, such as that used by Wacom based hardware, capacitive pens and resistive screens with pen shaped pointers. Although pen interaction supports complex input such as handwriting, text and accurate direct-interaction with a display, it necessitates bi-manual interaction and often occlusion of the display when used. Once touch and multi-touch screen technology become more readily available, these superseded pen interaction in commercial mobile devices, replacing pen based input with touchscreen keyboards for text entry. Pen technology is now re-emerging as a solution to complex data input[14] in combination with large multi-touch displays to expand the available input space for mobile devices. These commercial technologies still offer interaction opportunities centred on the display (for direct interaction), but drawing on experiences with table-top interaction, researchers have developed technologies such as 'SideSight' allowing mobile users to make use of the space around their device when placed on a surface by tracking the

[14] http://www.samsung.com/global/microsite/galaxynote/note/index.html?type=find

interaction of hands and fingers around its edge (Butler, Izadi, & Hodges, 2008), thus increasing the physical space for interaction allowing for more complex and non-occluding gestures. Similarly, the infrared approach by Kratz *et al.* (Kratz & Rohs, 2009) allows a user to perform course 3D gestures above the device whilst interacting with the touchscreen for more intricate gestures, making use of the space around the device when it is placed on a surface. A wide variety of gestures can now be captured by augmenting mobile technology in this way, including interaction with both sides of the device (E. E. Shen, Tsai, Chu, Hsu, & Chen, 2009) and clip-on tangibles augmenting the mobile display with physical buttons, knobs and sliders (Yu, Tsai, et al., 2011) to build tangible interfaces for mobile devices. These physical interaction possibilities are especially pertinent to the issues of direct manipulation and visible control when interacting in situated media production teams.

***Application and Hardware Development*** Until recent developments in mobile platforms that offer managed development environments high level operating systems, developing for small form factor devices was a complex and highly specialized workflow. The emergence of ecosystems such as iStore, Android and HTML5 has allowed these mobile technologies to be applied in low fidelity interaction prototypes rapidly and without specialist hardware knowledge, and provided a route to deploying these technologies to the research community through existing app store channels.

As a result of this smart mobile device industry development, the hardware technologies behind these devices are now cheaper and easier to integrate into custom hardware. This has resulted in a new type of prototyping platform emerging which allows non-experts to develop custom hardware with specific sensor and output functionality using high level managed languages and development tools. Systems such as .NET Gadgeteer (Villar, Scott, & Hodges, 2011), Arduino[15], mBed[16] and RaspberryPi[17] are all examples of easy to use prototyping platforms which can be augmented with sensors and deployed as stand-alone devices for interaction prototypes. These systems

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[15] http://arduino.cc/

[16] http://mbed.org/

[17] http://www.raspberrypi.org/

often maintain some of the functionality of mobile phones such as a small display,, sensor packages and communication ability, but these platforms enable the creation of mobile interactive systems not possible before due to their small size, low cost and low power consumption.

***Connectivity*** Collaborative systems integrating multiple personal and shared devices necessitate the development of robust communication technologies and strategies to support such interaction. Although many consumer personal interaction devices are now able to communicate through Wi-Fi, Bluetooth, RFID or Infrared, strategies have had to be developed to model and manage the communication between these disparate devices to provide a coherent interaction experience for all users. Technologies such as NFC and RFID have been used for face-to-face device communication (R. Wang & Quek, 2010), in which the technology enforces the physical constraints of touch the devices together, in contrast to (Kray, Rohs, Hook, & Kratz, 2009) where in practice, devices are constantly communicating through blue-tooth, but a social protocol is introduced to initiate the transfer of images between devices through moving them spatially close together on a table-top. Cell tower location (Naor, Levy, & Zwick, 2002) can be used to identify location and contextual information about the user's device, but within a collocated space this does not provide enough identifiable data. Bluetooth (Bargh & de Groote, 2008), Near Field Communication (NFC) (Kelkka, Kallonen, & Ikonen, 2009) and optical markers (Kray et al., 2009) have all been presented as alternatives for collocated identification of devices but these methods all require a device registration step to enter a shared workspace. When using small form factor personal interaction devices in a table-top environment, mobile devices can be modelled analogously to tangible interaction tools. In this way, the relative location and spatial arrangement of the mobile devices can be key factors in the interaction context of the system (Dix et al., 2000). Within a confined area, relative physical positioning of devices can be used to create new interaction modalities, such as those demonstrated by 'Siftables', small mobile interaction platforms representing data or functions which can be ordered in natural ways such as grouping and sequencing to facilitate composite functions (Merrill, Kalanithi, & Maes, 2007b), or in Kray *et al.*'s technique for photo sharing, users move their phones into particular areas on a table-top which are created relative to the phone depending on whether they are sharing or receiving photos amongst a group, encouraging users to physically move their phone near the target photo (Kray et al., 2009).

## Design Challenges

The integration of personal mobile interaction devices into a group context reveals key design challenges that impact onto the design of such collaborative systems. These challenges created by both the technical limitations of mobile devices and also the social challenges associated with integrating existing user's tools into new interaction scenarios.

***Eyes Free Interaction*** Media production crew must be responsive to the changes to the environment they are making, such as changing lighting in a public venue. During these operations it is vital that the operator can observe the changes as they happen, rather than looking at the point of interaction. Although using a mobile device allows them to position themselves in a better position to observe these results, similar issues in 'eyes-free' interaction appear for mobile devices as for table-tops, especially as the main interaction space for mobile devices might be a touch screen. To augment existing touchscreens for eyes-free interaction, haptic methods of eyes-free interaction such as 'TeslaTouch' provide haptic feedback of button locations (Bau, Poupyrev, Israr, & Harrison, 2010) to support 'searching' for controls on a display without looking. In the case of the 'Haptic Wristwatch', an additional input device is connected to the mobile device and mounted on the wrist, enabling in-air gestures and haptic feedback from the watch strap, without holding the mobile device (Pasquero, Stobbe, & Stonehouse, 2011). Examples such as 'Fooge': an audio and gesture input system (Dicke, Wolf, & Tal, 2010) and Pressure Menus (Wilson, Stewart, & Brewster, 2010) demonstrate the possibility of creating mobile, battery powered interfaces which still allow the user to look away or carry out other tasks whilst interacting with the device through the use of touch and known gestures languages.

***Small Screens*** Mobile platforms are portable and provide a rich personal interaction space for individual control but in many cases lack a large display area on which to present data to the user. On solution is to provide access to larger display areas which can be operated through the use of the personal device. By using the integrated rear-facing camera on a mobile phone, users can interact directly with a large display by looking ‘through’ their mobile device (Pears, Jackson, & Olivier, 2009) and interacting with content on a traditionally passive display, such as those in public places. On table-top interfaces, mobile devices can be used as ‘pointers’ (D. Schmidt, Seifert, Rukzio, & Gellersen, 2012), or as extra displays such as those used in ‘PokerTable’ for private interaction (Shirazi, Döring, Parvahan, Ahrens, & Schmidt, 2009), to both increase the screen area available and provide private screen areas for larger public displays. As pico-projectors are manufactured into some smart phones it is now possible to create a situation large display when required without any additional hardware (Wecker, Kuflik, Lanir, & Stock, 2012). Techniques such as ‘ShadowGestures’ can enable this larger impromptu display area to become interactive for both the individual and a group through performing gestures in front of the projected display using the on-board camera to track movement (Segen & Kumar, 1999). Similarly ‘TeleTorchlight’ enables a remote expert collaborator to ‘draw’ onto objects which their college is projecting a portable display to provide visual help during complex tasks (Suzuki & Klemmer, 2012).

***Sharing*** By introducing a personal interaction space to collaborative interaction scenarios with personal devices, the act of sharing becomes a complex design problem. Mobile devices afford the physical representation of sharing – by passing the device to someone else – but unlike a large table-top display, this action has to be initiated by the user, as the mobile display is not visible to all users all the time. ‘MobiComics’ is a collaborative comic creation tool which aims to explore elements of personal sharing using mobile devices. Users can create comic ‘tiles’ with their own device and add them to a ‘strip’ represented centrally by a large display (Lucero et al., 2012). By taking photos on their phone and augmenting them with speech bubbles and simple graphics, a comic strip is collaboratively created. The order of elements added to the central timeline is controlled by the relative position of the team members arranging the tiles, forcing the group to manifest the order of the tiles in space with themselves. By using personal mobile devices to create and manipulate content, users are given expressive and intricate interactions to produce tiles in their own time, and are able to control who it is shared with before deciding to share on the larger display. By fostering a playful style of interaction, ‘MobiComics’ facilitates creative and spontaneous interaction amongst members of the group. Users can choose to share their work in progress by handing the device around, or conceal their intentions until they are ready, all by controlling access to their own device. In ‘Mobiphos’, a system which facilitates the instant capture, sharing and collection of photos amongst a group of mobile users (Clawson, Voida, Patel, & Lyons, 2008), each user is presented with an identical set of functions: ‘capture’, ‘share’ and ‘store’ on their personal device. In both these scenarios, replicated functionality is provided across all mobile devices enforcing a democratic workflow. In these cases, social protocols emerge to facilitate order within the team, allowing flexible reconfiguration of team structure and roles during the task.

## 2.5 Conclusion

In this chapter I have presented a broad review of the literature surrounding situated media production. I described how the field of CSCW has tools to describe collaborative media production teams and the complex dynamics that affect such co-located environments. Drawing on research from across CSCW I then wrote a broad review of the available collaborative technologies that present affordances and design opportunities for enabling media production teams. In particular I highlighted how these technologies present opportunities for designing interfaces that enable interaction given the situational factors impacting situated media production. I draw on these previous examples of interaction technologies to inform the design of StoryCrate and ProductionCrate.

# Chapter 3. Situated TV Production

*WITH STORYCRATE*

## 3.1 Introduction

TV production teams are under continuous pressure to produce ever more creative and ground breaking content while reducing the financial and human resources required. These demands on the industry for efficiency have led to a reduction in the size of on-set production crews and an associated increase in the multi-skilling of team members. The industry has also seen a rise in the use of digital productivity tools both to integrate stages of production (e.g. through creation and use of metadata) and to improve creative working practices. My focus is on the stage of the production process most affected by the situational factors introduced in Chapter 1, the capture of footage during the 'shoot' phase. The 'shoot' brings together many skilled professionals into a setting that can often be a remote location where time, environmental and coordination factors have a significant impact on production decisions. It is with this context in mind that I have designed and evaluated StoryCrate, a tool to aid the creativity of production teams undertaking on-location TV 'shoots'.

The BBC (British Broadcasting Corporation) has for many years been at the cutting edge of broadcast technology research, developing innovative technologies in all areas of the production process from the enhancement of viewing experience, including Teletext, video on demand (VOD) services and digital television standards, through to new production infrastructures such as digital capture. Recently the BBC has developed a set of digital workflow tools to improve efficiency in the production process by removing tapes from the workflow entirely (Cunningham & de Nier, 2007), enabling a faster workflow from capture to broadcast. StoryCrate has been developed as a collaborative project with BBC Research and Development to integrate in-house digital production workflow tools with new interaction techniques and technologies. While technologies are under development for digitizing and streamlining the modular production workflow, driving efficiency and increased production quality, few tools target the shooting phase of production. Within this process-driven style of workflow, during the shooting phase, the creative decisions made by the crew are reduced to a single set of paper notes, and the captured video footage. This information alone is transferred to the editing and post-production phases, resulting in lost understanding of the decisions made during the shoot.

I developed StoryCrate to scaffold creative practice within the shooting phase of production to support a continually creative process for all members of the crew. I aimed to develop a tool that harnessed the skills of the crew already present on location to produce better quality content and facilitate communication of creative decisions to later production processes. Through the use of StoryCrate, creative practice would be supported on-site, and the decisions made using StoryCrate would be transferred in context and in more detail to post production phases of the workflow. I start by exploring the specific aspects of creative practice within the on-location production phase that can be supported, drawing on these elements to develop a technology and interaction design for StoryCrate that enables such practices within the team. In the subsequent chapter I describe how StoryCrate was deployed within a real-world production environment, and discuss the design decisions I made in relation to the resulting use by the production team, drawing out design recommendations for designing tools to support creative practice within situated production.

## 3.2 Related Broadcast Research

Previous related research in HCI and CSCW has generally focussed on live broadcast production environments such as sports events (Engstrom et al., 2008; Marriott, 2000; Nou & Sjolinder, 2011). On-location TV production is where a production crew sets up a film shoot to produce creative and entertaining content that will be broadcast at a later date. Unlike live broadcasts, creative decisions in these TV productions are not made at the point in time of transmission (Broth, 2004), but throughout the production process. However, on-location scenarios are time constrained, and factors such as outdoor light, weather, location access, crew availability and cost all impact on the time available. Previous studies have described the complex communication and technological tools that already exist to support television production content creation (Verna, 1987) and these findings have been used as a basis for the design of mobile production tools (Engstrom et al., 2008) for augmenting the collaborative creative process. However, such applications have a particular relevance for the communication between team members in *distributed* environments, rather than those of co-located production.

Outside of broadcast production team-based video production technologies, example systems such as MediaCrate (Bartindale, Hook, & Olivier, 2009a) explored the deployment of co-located shared digital spaces to represent complex video data for multi-channel video mixing. MediaCrate was designed for environments that share situational factors with TV production, such as a complex multi-skilled team structure. However, it was not specifically designed to augment an existing workflow or support creative practice but instead aimed to support role changing and multi-tasking within the production team when creating a singular directed narrative of a live event, and the routing and mixing of video to multiple locations (Martin & Holtzman, 2010). In other collaborative creative scenarios, technologies have been deployed to engage users with creative practice and drive the creative media process. Notions of action externalization (Warr & O'Neill, 2007), tool flexibility (Nakakoji, Yamamoto, Akaishi, & Hori, 2005) and team communication (Firestien & McCowan, 1988) have all been shown to be advantageous to supporting creativity in team scenarios, but few amongst these examples propose tools targeted specifically at using interaction technology as a means to engage crew in the television production process, and in particular the on-location workflow. Our understanding of these teams and their complexities has increased however, and such teams have been observed to be adaptable, effective under pressure, multi-skilled and reflexive to the changing requirements of their roles (Carter & West, 1998). Within the wider culture of TV production, it has been noted that 'industrial reflexivity', or the ability for the industry to evolve processes in response to new techniques and technologies, is a distinguishing feature of this media production industry (Caldwell, 2008).

## 3.3 Making Television

A new ecology of creative content production is emerging, driven by digitalised production technologies and increased demand for high quality content. Rather than being separated into a few large production companies which maintain a permanent staff of skilled employees, over the last 10 years the industry has seen a move towards 'clustered' groups of smaller specialist companies in localised geographical areas

(Bassett, Griffiths, & Smith, 2002), each specializing in particular areas of the production workflow, or types of content. Through this shift to contractor working, freelance production crew are turning to multi-skilling across production roles as a way of finding reliable work within the sector. Against this background however, the systematic production workflow for creating TV has stayed relatively constant The technical process of TV production is well documented and understood, and common procedures, practices, team structures and role hierarchies exist that enable new crew members to integrate quickly and efficiently into existing workflows (J. Harrison, 2000). I constructed a model of a typical production process from my observations of BBC production workflows and interaction with professional crew members to build an understanding of the current workflow. To understand the effect of StoryCrate on such TV production processes, it is germane to describe what constitutes a 'typical' shoot and how creative practice is supported and valued within the existing crew structure.

TV production for pre-recorded content is a unique and complex process in which crew members skilled in specific production roles collaboratively produce a singular creative output (Verna, 1987). Many of these roles are highly reliant on advanced or proprietary digital technologies and along with developments in camera optics, HD recording and cloud media storage, these tools are having a significant impact on production practices. Although aspects of each production process vary between programmes, genres and production houses, workflows share many common properties which can be found in productions ranging from blockbuster movie sets with hundreds of crew to wildlife documentaries with three multi-skilled team members. The process has seven distinct stages in which different teams of people contribute to the workflow at a variety of locations at different times throughout the production process. An example of such a workflow, shown in Figure 4, follows a linear process in which the output of each stage is fed into the next:

(i) A program concept is developed through a group creative process initiated from an idea proposed to a commissioning organisation. This process outputs a 'treatment' document outlining storyline, content and style.

(ii) The developed concept is written as a script and put through multiple revisions. The final script includes stage direction, location information and complete dialogue split into scenes.

(iii) The Director and Director of Photography take the script and design camera angles for each shot, listing focus, lighting and cutaways.
(iv) A logistical shooting plan is drawn up by the producer from the camera plan, and called the 'shoot order'. This document combines location and cast availability, crew and budgetary constraints into a step by step timeline of the shoot.
(v) The shoot order is followed by the crew on set, and annotated with metadata by hand in a standard 'tramline' format e.g. "boom in shot" or "incorrect dialogue".
(vi) The raw footage, 'tramlines' and script are passed to an Editor, who works with the Director to produce a final edit for broadcast.
(vii) The single edited film is broadcast.

Systems such as INGEX (Varney & Fensham, 2000) developed by the BBC for tape-less recording, and BBC Redux[18] for distribution, archiving and playlist creation, are innovations that have digitized the workflow infrastructure and interconnections between them. Although these systems offer technology advancements in capture, transport and storage of content, they do not directly support the on-location shooting process, or specifically support creative practice amongst the team.

For example, during the editing phase the Director and Editor must work with large amounts of raw footage, a time-consuming manual task often requiring re-reading of numerous paper annotations made on location by other members of the production team. The phase in which these annotations are made, the 'shoot', is often the most expensive and unpredictable stage of the production process. It is in this phase of the workflow that a large group of creative professionals come together to capture base video footage in a limited time frame which will be used by the Editor to create a final edit. It is this context into which StoryCrate was designed and deployed, but currently few tools exist to support the creative decisions made by the crew for use in later phases of the workflow. Although I use this as the typical workflow, many productions do not follow this strict order and configuration of processes, and in particular, the introduction of new production tools affects this workflow.

[18] http://en.wikipedia.org/wiki/BBC_Redux


*Figure 4 A Typical TV Production Workflow*

Figure 4 shows the 7 stages of a typical production workflow. In the Concept Development phase a Script Editor oversees the writing of around five script drafts. The scripts define the activities in the pre-production and production phases that are necessary for content generation as well as the overall vision. In the eight to ten weeks of Script Writing and Shoot Preparation, complex or expensive sequences may be storyboarded (although this is not common practice), and the Script Supervisor prepares the scripts for filming by producing a shoot order of planned camera angles, minimising logistical manoeuvres and hardware requirements.

In the Filming on Location phase, footage is not captured in the order that the viewer will watch it during broadcast, but rather in an order defined by the production team to maximise efficiency, responding to the availability of locations, sets, actors and equipment. As each piece of footage (or 'take') is shot (or 'captured'), it is logged by the Script Supervisor, who numbers it and logs details about duration, type of shot and quality against the master list of required content. This meta-data is passed to the editing team for later use during post-production to navigate and filter the large amounts of raw footage generated by the shoot. All outdoor scenes are usually shot first, to aid continuity with the indoor scenes which follow later in the schedule. Traditionally the Director maintains a conceptual overview of the whole production and has overall creative control during this phase of the production. The Director is responsible for delivering an interpretation of the vision (sometimes their own) defined in the development phase of production.

This vision is communicated through a hierarchy of roles (Figure 5) to the Script Supervisor, Camera Operator, and 1st Assistant Director (1st AD). The number of roles and the arrangement of tiers however, may vary according to the size and type of production, e.g. the Script Supervisor and 1st AD roles may be assumed by a single crew member in a small production. The Script Supervisor checks for continuity, and checks shots against the script and the 1st AD performs the practical management and logistics for the rest of the crew (Sound, Lighting and Runner). Sound crew members work alongside the camera operators to provide accurate and clean sound recording, using radio and ambient microphones to capture audio. During this phase, lighting engineers use a variety of technology and techniques to reproduce specific lighting conditions (and ambiances) for particular scenes. Runners are responsible for general logistics, people management and non-skilled work on the set. These crew members rely on direct instruction from their superiors for creative direction, using their experience and skill to effectuate these decisions.

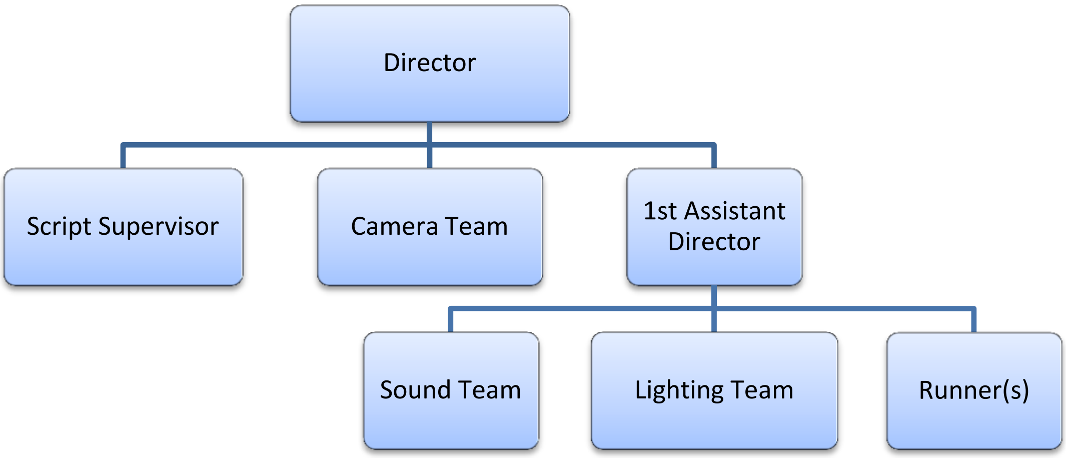


*Figure 5 A Typical TV Crew Hierarchy during a Shoot*

The infrastructure technologies currently under development facilitate efficient transfer of content and meta-data through the production workflow from shooting to broadcast. Rather than facilitating data transfer forwards through the workflow, the proposal is to support crew making creative decisions during the shoot that would that would otherwise have been performed in the editing and post-production phases. Better support for creative decision-making earlier in the production workflow, and better capture and communication of these decisions could reduce the time currently spent searching and interpreting notes for clips during the editing phase. By supporting the creative process in this earlier phase of production, I can promote creative practice on location and capitalize on the availability of skilled production team members and their proximity to the shoot. StoryCrate is a technology that aims to facilitate, record and allow the transfer of these creative decisions to post-shoot phases of the production process.

The Director's vision sets the creative agenda for the shoot, and the Director makes all principle creative decisions during the filming process. This necessitates clear communication of the Director's decisions to the rest of the team so that they have enough information to perform their roles effectively. Production teams are organized hierarchically, where both physical and organisation distance from the Director within the hierarchy directly corresponds to an individual's awareness of the overall shoot progress, their creative rationale and the end result of their actions. To put this in context, often only the Director and camera crew see any footage until after the editing phase, when the final product is broadcast. Indeed, although the crew works collectively towards producing captured footage, each individual member of the team has no direct feedback on the quality of their input into the process until after the production is complete. In addition, many editorial decisions made during the shooting phase are not acted upon immediately, but are recorded as notes or meta-data that the director and editor will use during the editing process. These hierarchical teams, which can be observed throughout the television production industry, generally perform well in cases where the production team has a rigid and well defined production process and a fixed script. It is less appropriate however for smaller, multi-skilled teams limited by tighter budget and equipment constraints, which are expected to produce content from scripting to broadcast much quicker. This type of team has emerged from the increased multi-skilling of production crew in the industry, and is particular common within smaller production companies where resources are limited.

My goal was to develop digital tools to support creative decision-making and the production process of these smaller teams. Often these teams do not have the resources for lengthy pre and post production phases of the workflow, and are under significant time and financial pressures. As such their primary outlay is during the shooting phase. Within the shooting phase, smaller crews may not have the large technical and logistical infrastructure support that larger established organisations have at their disposal. Whereas in larger production teams multiple crew members might perform the same role, necessitating a rigid hierarchical team structure for efficiency and communication amongst the team, in smaller teams not all of these roles may be filled. Such teams can thus be more responsive to changes to the script, content and environment. Through StoryCrate, I aim to scaffold the creative practice of smaller teams through supporting their own practices, making best use of the limited resources that are available for these types of productions.

My hypothesis is that by creating a shared, visible representation of the shoot phase of production available throughout the shoot I can push the point at which creative decisions are made (such as which shots to make use of in the final edit) to an earlier process in the production workflow. These decisions can be represented by meta-data attached to the media at the point of capture as attributes and rough edit choices stored non-destructively. This meta-data can then be available for members of the production crew during the editing phase of production. By supporting decision making and creative practice in the shoot production phase, the production can leverage creative skills from a larger number of team members and the number of decisions that have to be made at edit time (using interpreted data) can be reduced. By enabling crew members to have more awareness of the effect of their role on content creation I aim to improve the output of the shoot phase through:

(i) Facilitating more flexibility and opportunities for trying new ideas.
(ii) Allowing the transfer of production notes transparently between processes.
(iii) Facilitating creative contribution by all members of the production team.

## 3.4 Scaffolding Creativity

Professional production crew rely on particular pieces of equipment to perform their roles. Often their skill and experience are directly applicable to specific makes and models of equipment and in turn, the features of the equipment define the workflow that is carried out by the crew. Rather than designing a tool to support creativity within a specific media production task (such as sound recording), the aim is to facilitate the creative practices that are shared across the team, supporting collaboration between individuals within their specific creative roles to improve both their individual practice and the group as a whole. StoryCrate provides a central representation of the shared responsibilities of the team independently of their existing equipment, facilitating shared awareness of the shoot progress. To design a collaborative tool to support these creative processes, it is important to first understand the range of practices through which the creativity of such collaborative production teams is realised.

Baer *et al*.'s work on creative practice suggests that creative practices are highly domain specific, and thus creative practice is best understood in terms of specific describable user events (Baer, 1998). Taken alongside a review of the literature on creativity, including Shneiderman *et al*.'s extensive work on the fundamentals of actionable creativity, previous work reveals a list of key high-level practical issues to consider when designing tools to facilitate creative practice (Shneiderman, 2007). By drawing on aspects of actionable creativity within this literature, collaborative creative practice within production can be categorized according to six themes. Although the measurement of such creativity in-the-wild is an open challenge for the creativity studies community, these six key actionable elements of creative practice provide a set of observable characteristics which embody creative practice within the workflow.

**Exploring Alternatives:** Throughout the production process, existing content is a key trigger of creative alternatives and possibilities; crew explore content alternatives, either spontaneously or stimulated by existing content, and add these new ideas to the collection of creative alternatives. Tools can be designed to support this process; for example Santanen *et al*. argues that "the likelihood of new association formation is an inverse function of cognitive load" (Santanen, Briggs, & Vreede, 2003), suggesting that designing an interface that reduces cognitive load will facilitate creative use of a new technology by allowing users to contemplate other creative possibilities whilst performing concurrent tasks.

**Changing Roles:** Since the class of crew member considered here is multi-skilled, when crew members change roles (either explicitly or by intervening in the activities of others), they apply their inherent knowledge and skills learnt from past experience implicitly to other roles they perform, leveraging their skills for alternative tasks. Crew members can change roles depending on situational factors, sharing experience and skills dynamically throughout the production process without explicit intention to multi-skill. In the 'Handbook of Creativity', Yamamoto discusses how role flexibility within a scenario leads to a higher creative output within a group (Yamamoto, 1963). By designing tools that facilitate scenarios in which production crew can either multi-skill or become involved in the practice of another role, implicit creative transfer can take place between crew members.

**Linking to the Unexpected:** In addition to exploring directly linked alternatives between content, I can consider team members' spontaneous deployment of unexpected or unplanned processes to accomplish tasks as a measure of collective creativity. Controversially, Goldenberg suggests that rather than allowing users to explore a large possibility space, defining structure within a domain leads to a more creative team, as team members are not overwhelmed by numerous possible actions (Goldenberg, 1999). By carefully crafting tools to avoid constrained workflows and by limiting the number of tools presented to the production team, there is a loose expectation of how users should appropriate the tools, which actually encourages the user to explore alternatives. These *unexpected* outputs may be new ideas that don't relate exactly to the task in hand, but that drive the creative process further by linking unrelated ideas together, binding practices, processes, content or people together from otherwise un-related areas.

**Externalization of Actions:** Each individual crew member constructs and manipulates an internal representation of the production when engaging with the shoot process. This personal representation is used to drive their creative input within their own practice, allowing them to create associations, guide future tasks and reflect on past actions. If members within a team have access to each other's representations, they are less limited by their own understanding of the situation and can use these external inputs as triggers for their own creative decisions. Warr *et al*. demonstrate that although externally triggered new ideas can be generated by interpersonal verbal communication, participants in their study found an external representation added additional context and a new level of situational understanding enabling more creative group work (Warr & O'Neill, 2007).

**Group Communication:** CSCW research has identified a variety of communication modes that are used by team members during collaborative tasks such as body language, conversation, notes and physical objects. Facilitating a wide range of interaction types and styles using production technology can lead to richer inter-personal communication, and subsequently a quicker and clearer understanding of each other's ideas. This communication can be explicit, e.g. where users engage in verbal exchanges, but also occurs as a result of non-verbal or 'back channel' behaviour, in which users observe non-verbal cues from one another. Firestien *et al*. describe "a synergistic relationship between the field of creative problem solving and communication", suggesting that creative practice and team communication are inherently linked and therefore tools that support creative practice should also support team communication (Firestien & McCowan, 1988).

**Random Access:** Traditionally within computer science, the term 'random access' describes the ability to access data out of sequence and at any time. In an existing media production context, the ability to playback and reference media outside of the linear workflow (only one thing if filmed at once), and that was recorded at other times is an important capability embodied by NLE (Non Linear Editing) systems during the editing phase of production workflows. When not limited to a linear production workflow, crew are able to construct conceptual and other (e.g. stylistic) links between a wider range of content. Hocevar *et al*. describe the process of creating abstract relational links between un-related content as "divergent thinking", and talk about the need to design for "fluency, flexibility, originality, redefinition and elaboration" to facilitate creative practice (Hocevar, 1981). For production tool design, providing the ability to browse media and production content related to the shoot could facilitate crew members exploring both the creative possibilities and reflection on previous creative decisions.

## 3.5 Storyboarding

During TV production shoots the creative vision of the writer is maintained and shared with the crew in the form of a script which pays particular attention to dialogue, characters, action and narrative. A director (with assistance from the camera operator) interprets the script and turns it into a sequence of camera angles or 'shots', e.g. close-ups, over-the-shoulder and cutaways of objects. Combined with chosen locations these are used to arrange the shooting timetable, actors' call sheets and equipment usage, recorded as the 'shoot order'. This order is the master plan that the crew follow during the shooting phase of production.

The script can sometimes be visualized using a still image of each shot (see Figure 6) laid out alongside the script, called a storyboard. Most often this is a sequence of stylized drawings, representing characters, props, camera angles and perspectives (Tumminello, 2005).

*Figure 6 An Example Storyboard Strip, with one tile for each shot change.*

In the last two decades, only large budget productions such as Hollywood blockbusters have used storyboards, and usually only to plan high-risk sequences and special effects to reduce re-shoot costs and manage risk. Before the advent of digital filmmaking, storyboards were used extensively for smaller productions and documentaries. The process of planning and creating storyboards was a time-intensive, but valuable and money-saving, part of the workflow in which a cross section of the crew would pre-plan all required shots to reduce lengthy camera setups, reduce the amount of expensive celluloid required and keep tape slicing to a minimum (Hart, 1999). In modern television production storyboarding has been phased out in response to the availability of cheaper film processes and easier to move equipment. Subsequently, a representation of each shot is produced by, and distributed to, a much smaller subset of the production team (often just the director), may not consist of a full pictorial storyboard or may not be produced at all.

Interestingly, storyboards have a long standing history within the digital media community outside of broadcast production as a rich method of representing video timelines. They have been augmented with technology to display digital information alongside video (Goldman, Curless, Salesin, & Seitz, 2006) and collaborative technologies have been developed that make use of storyboarding for group editing (Harada, Tanaka, Ogawa, & Hara, 1996). Unfortunately since the use of storyboards is uncommon in current TV production workflows (Tumminello, 2005), these technological innovations have not yet been transferred to broadcast environments. An unintentional side effect of not producing storyboards is losing an external representation of the film shoot (i.e. a representation that is visible and shared between all members of the production team). While other functionally equivalent representations exist that allow information to be shared (e.g. timetables, shooting orders) storyboards are a familiar, simple to use, and easily interpreted means of representing the creative goals of a production. Given that many broadcast professionals have some experience with non-linear video editing software in which clips are digitally represented using storyboards, introducing this representation back into the location shoot workflow would seem appropriate. For the design of StoryCrate I chose to revisit the notion of a storyboard in digital form, as a dynamic shared representation for collaborative use during the film shoot. Consequently, StoryCrate uses a storyboard as the primary representation of the current film shoot.

## 3.6 Supporting Creative Practice

Defining discrete elements of collaboratively driven content creation informed the design process of StoryCrate, helping us to shape key elements of the design that support specific creative practices within the production team. These designs were developed through a process of:

(i) Mapping the thematic categorization of creative processes onto the roles, skills, processes, social constraints and existing workflows of a television shoot.

(ii) Selecting, configuring and developing interaction technologies and techniques to support these mappings whilst respecting the practical constraints of television production.

### *3.6.1 Mapping Creative Practice to the Workflow*

Due to the physically distributed nature of a film crew during a shoot, facilitating peripheral awareness of individual team members to support externalisation of actions was a key requirement of the design. Interfaces to support peripheral awareness are often deployed to provide situated contextual information in multi-user environments. Slideshow is a typical example of such an interface which allows users to both directly and indirectly assimilate information from the rest of the team that is relevant to their own task (Cadiz, Venolia, Jancke, & Gupta, 2002). While peripheral awareness underpins a number of the creative practices identified (e.g. externalisation of actions and changing roles), it was important to also be sensitive to the distinct professional roles of the crew and the varying demands placed on them spatially (where they need to be on the set), temporally (when something is happening) and cognitively (ability to perform extra tasks). In such a context, it was important that peripheral information would not be distracting for the crew performing their existing roles.

Although Storyboards are currently not utilized during film small productions of this type or scale, they provide a rich representation of the state of the shoot and can be augmented with additional meta-data that has meaning for multiple crew members. Typical practice is that the shoot order is the only representation other than the script that is available on a shoot, but this is a practical representation only of shoot logistics, and so providing a shared representation of the on-going creative output would be beneficial for the crew. Placing this representation within easy reach of all members of the team increases the possible chance of crew members engaging with the interface, encouraging spontaneous use and the exploration of alternatives without the risk of having leaving the relative safety of their natural location within the environment.

By providing a limited selection of tools to manipulate this shared representation of the shoot I can support crew members re-purposing the interface to reflect the requirements of their own role. When placing this in a centralised context, with a single point of interaction, the group can be encouraged to group together and communicate about creative decisions, discussions which would not have happened without a shared space around which to gather. Outside of these gatherings, crew can randomly access any content that has been captured during the shoot, using digital video playback and storage technologies to present content back to the crew.

### *3.6.2 Technology Selection to Support Creative Practice*

Table-top interfaces are uniquely equipped to provide a collaborative platform for developing centralised co-located interaction. Table-tops not only afford co-located collaboration and peripheral awareness through large form factor displays, but readily support tangible interaction. They can be cast in a physical form that is both appropriate to busy production environments with unpredictable environmental conditions and does not appear intimidating to crew members. Through a large form factor, high resolution display, large amounts of detailed information can be displayed concurrently and this information can be viewed from a distance, enabling proxy interaction with the interface by remote members of the team.

Tangible interaction was chosen as the primary input technology for StoryCrate, particularly due to three key affordances for interaction: limiting the number of interaction tools for each interface function, which forces crew members to communicate their intentions with each other in order to retrieve and operate the tool; interactions with large tangibles are easy to observe from a distance, such as from the other side of a film shoot so that crew can be more easily peripherally aware of current actions occurring at the interface; tangibles can implicitly manifest functional constraints of the interface; tangibles can act as physical access tokens limiting functions by possession of a control. Often, members of the production crew are already carrying multiple items (e.g. radio, clipboard, cameras, props, coffee, scripts) and in order to engage with an interface, it must be possible to place these objects down to interact. By disabling touch interaction on the table-top interface, un-intended interaction with the display is prevented. Additionally, when not in use, StoryCrate can be used as traditional table, saving unused space in smaller shoots.

Current infrastructure dictates that video equipment be physically connected by cables to operate reliably and must meet the speed and processing demands of high bandwidth video. StoryCrate was fitted with the latest consumer PC hardware to allow for these demanding applications. As film shoots can be in any location, StoryCrate must be easy to transport, configure and operate outside of an environmentally controlled setting such as an indoor studio. Furthermore, production crews are naturally reticent about new or untested equipment, and it is therefore desirable that any prototype has a 'look and feel' that is consistent with traditional equipment and requires as little specialist knowledge to operate as is possible. For this reason, I chose to install StoryCrate into a 'flight-case', making it both robust and easy to transport.

### *3.6.3 Putting it Together*

StoryCrate is a hardware and software prototype designed to be taken onto a filming location and operated by the crew. It combines a custom hardware interface with bespoke software to provide a film crew with a state representation of the current shoot progress in terms of a pictorial storyboard. The crew start a shoot with a pre-prepared storyboard which they gradually replace with real footage coming from cameras on set. Simple editing, meta-data notation and clip organisation tasks can be performed using StoryCrate. StoryCrate is a single self-contained, portable flight case which opens to reveal a high resolution tangible interaction surface, produced by two rear projected displays horizontally mounted below two vertically mounted LCD preview monitors (see Figure 7).

A timeline representation of the current output programme is displayed on the largest area of the interaction area and footage appears directly on a ‘shelf’ (top left) area of the display after being filmed and retrieved from the digital recording system. This footage can be inserted into the pre-prepared storyboard of still images, presented visually as a timeline on the horizontal surface. Tangible plastic tiles placed and manipulated on the surface of the display are used to perform simple trim, move and remove operations, analogous to non-linear editing tools such as Final Cut Pro[19], on video and meta-data. A regular keyboard and Anoto pen are provided to customize or add new media content. At the end of the shoot, the resulting edit, including all meta-data, is exported to the Editor’s system for the Post Production phase of the workflow.

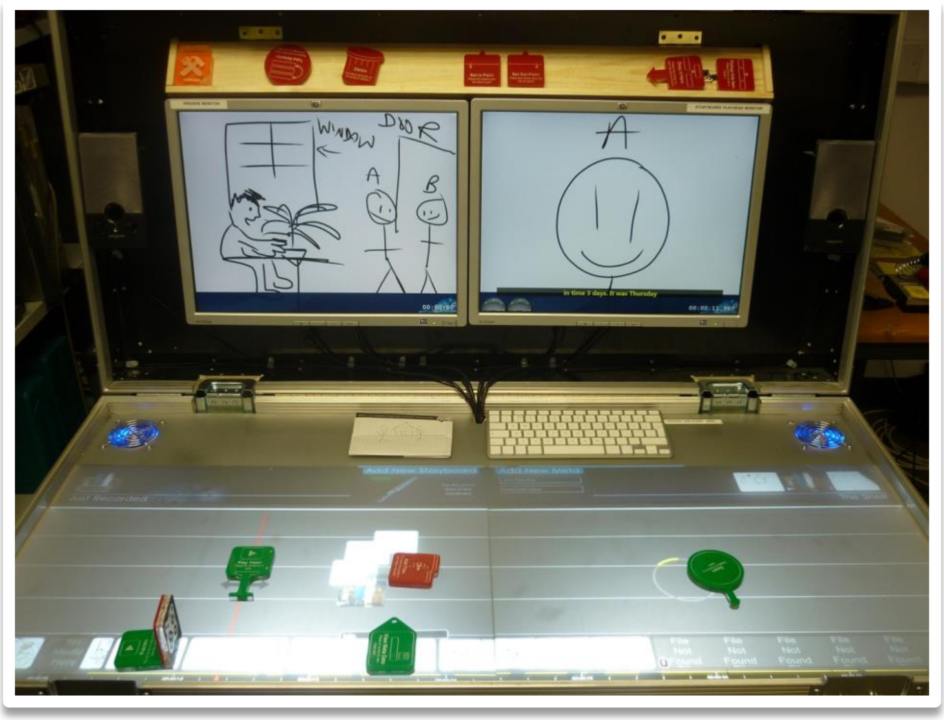


*Figure 7 StoryCrate: Tangible Editing Interface*

[19] http://www.apple.com/finalcutpro/

StoryCrate is built to take on location, and connects via Ethernet to a digital recording system used by the BBC. StoryCrate uses Secure Shell to connect to the Linux based tape-less recording system and monitors the current shoot recording directory, downloading new clips and XML metadata as they are created by the recording system. StoryCrate keeps track of all media recorded during the shoot so that content can be used at any point, regardless of when it was filmed, providing random access to content for users. Before shooting, StoryCrate is pre-loaded with a storyboard (created in Final Cut Pro) and exported as AppleXML[20], a format that contains the script, shot descriptions and storyboard images edited with expected timings. On StoryCrate, this is represented as a linear timeline, where each media item is represented as a thumbnail of the media on the display. Almost the entire display is filled with this shared representation of filming state, providing users with a single focal point for keeping track of group progress. During the shoot, a take or clip immediately appears on the device shortly after it is filmed, and can be manipulated and previewed on StoryCrate as a thumbnail. The interface is based on a multi-track video editor, with time represented horizontally, and multiple takes of a shot vertically (elements (1) and (2) in Figure 14).

## 3.7 Hardware Design

The hardware and software that comprise StoryCrate were developed alongside each other. Situational factors of shoot environments and the design elements that I have identified to support collaborative creative practice in these types of scenarios guided the design choices that I describe here.

### *3.7.1 Physical*

All of the technology needed to operate StoryCrate and the associated hardware is housed in a 1.5m long trunk fight-case mounted on 8cm castors manufactured from 6mm ABS coated plywood with aluminium and steel corner fixings and edge frames. The dimensions of StoryCrate were based on both the standard sizing of a transport case for easy logistical management, and the likely available amount of space to

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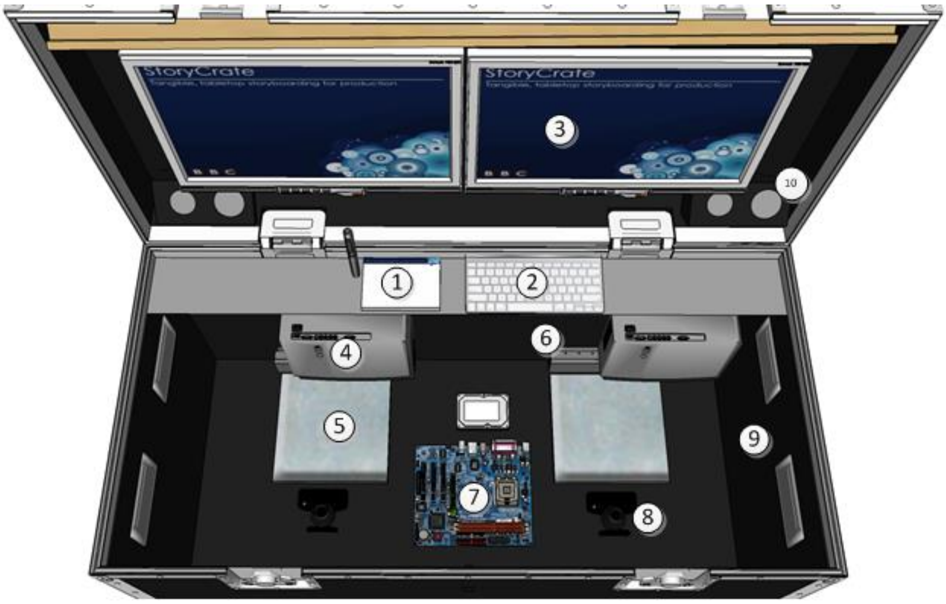
https://developer.apple.com/library/mac/documentation/FinalCutProX/Reference/FinalCutProXXMLFormat/Introduction/Introduction.html deploy such a device on a variety of locations. It was built to be robust and easily transportable to shoot locations, fitting inside a variety of transport vehicles. This 'tough' aesthetic is common amongst production equipment and lends authenticity to the prototype, as well as providing practical features such as a robust housing. Combining the entire unit into a single package was key for scenarios with more extreme environmental situational factors, such as limited on-site space.




**Key**
1. Anoto Pad, 2. Keyboard, 3. Preview monitors, 4. Short-throw projectors, 5. Mirror, 6. IR emitter, 7. PC components, 8. USB Camera, 9. Flightcase housing, 10. Speakers

*Figure 8 StoryCrate Internal Hardware Layout*

### *3.7.2 Computation*

StoryCrate's primary computational hardware consists of a standard desktop computer located inside the unit. This consists of: a quad core 2.8GHz processor, two dual head graphics cards, Bluetooth connectivity, networking and SATA hard disk drive. This PC operates on Windows 7 Professional and logs in automatically on boot. Additionally an Acer Revo net-top PC, running on the second camera's tangible tracking system is installed in the unit, networked via a router to the primary PC. This PC runs Windows XP, auto-boots on power up, and auto-starts the tracking software for half the display on boot. Everything auto-starts when the device is connected so that no extra technical skills are required by the production team to start using the system.

### *3.7.3 Display Surfaces*

StoryCrate presents three displays to the user. On opening, two 22” 4x3 LCD displays are presented side-by-side vertically, attached to the inside of the flight-case lid. The third display is presented as a widescreen high-resolution table-top display positioned at the top edge of the flight-case. This table-top display is rear-projected using two short-throw DLP BenQ video projectors which project images into the base of the unit, providing a 2560 x 1024 pixel display area. This image is reflected off two front-surface mirrors back onto the underside of the table-top to increase the size of the image. A 60” x 25” sheet of transparent 6mm acrylic with a self-adhesive diffuse coating provides a projection surface for rear projection, and the physical table surface. This surface is robust and does not scratch easily, allowing items to be placed on the surface without harm to the technology, whilst the crew interact with the system.

### *3.7.4 Input Technology*

Most actions are performed by physically manipulating acrylic *control* objects which when placed on the table-top perform contextual interactions with elements on the display; Figure 10 shows the entire set of objects that can be used in this way. These tiles are optically tracked using the Diffuse Illumination (Müller-Tomfelde, 2010) technique when placed on the surface of the table-top display. Each tile presents a unique, asymmetric pattern (called a fiducial) printed on its underside which is visible to two “PlayStation 3 EyeCam” cameras placed beneath the surface of the display.

An instance of the ReacTiVision (Kaltenbrunner & Bencina, 2007) tracking software connects to each of the two cameras, optically tracking the markers and transmitting position, rotation and presence information via the TUIO (Open Sound Control, a UDP based protocol)[21] to the StoryCrate software system. To avoid the projected display causing interference and reflection from the tangible objects into the cameras, the tracking system operates in the Infrared spectrum with a wavelength of 980nm rather than the visible spectrum.

[21] http://tuio.org

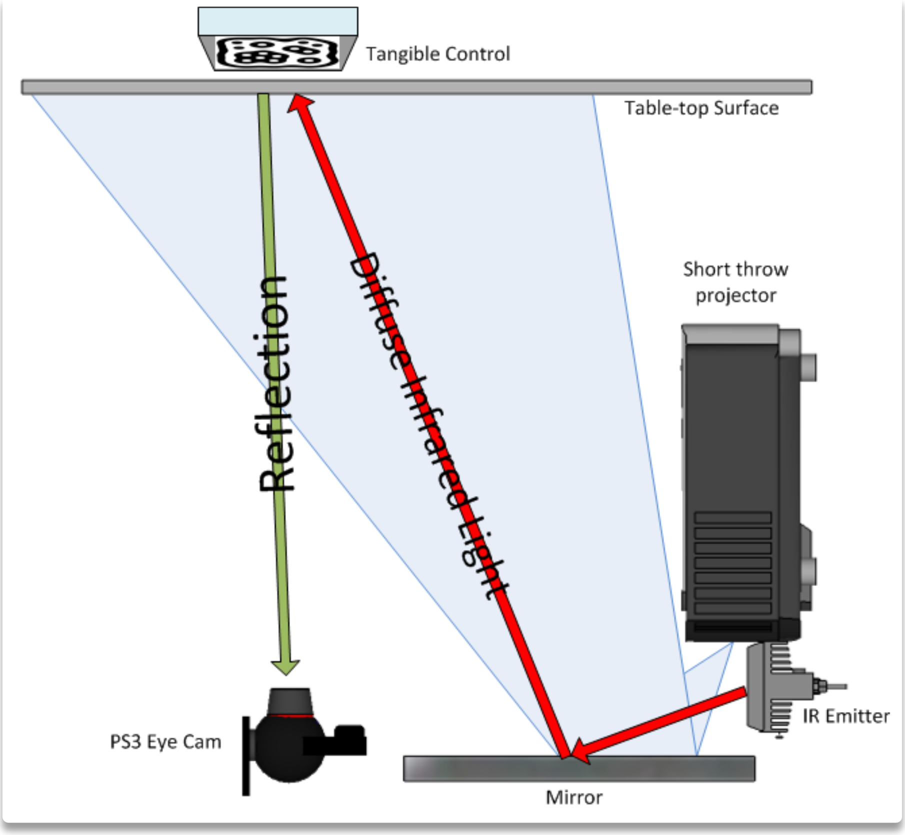



*Figure 9 Diffuse Illumination Configuration*

To provide sufficient illumination and optical contrast for tracking the underside of the fiducials, two large Infrared emitters are placed inside StoryCrate to provide a bright but diffuse illumination source. To create tangible markers that were a manageable size for operators (40mm x 40mm), a high camera tracking resolution was required in order to distinguish individual markers at this size. Rather than use a single high resolution camera in the centre of the unit, and to contend with the large amounts of lens curvature or “fish-eye” effect of a lens with a short focal length, two cameras operating at 640x480 pixels were installed side by side in the base of StoryCrate with a small amount of overlap (approx. 5cm laterally at the focus plane). As a side effect, this also provided a fall-back system in case one of the two tracking systems failed during operation, allowing users to operate on 50% of the interface.

Each tile is manufactured from laser-cut 6mm transparent acrylic sheet, cut into an iconographic shape (approx. 40mm x 40mm) relating to the function it performs, these tiles are simple shapes that can be identified at distance from across the shoot. A 3mm coloured layer of acrylic is affixed onto the top, engraved with additional information including the name of function the tile relates to. Tiles which perform data-manipulation functions are separated in colour from those which perform view functions. A laser printed marker is affixed to the underside of each tile and covered with a protective film to protect against prolonged use.


*Figure 10 The Available Tangible Tiles for Use in StoryCrate*

StoryCrate uses a tracking system that tracks non-electronic (inactive) markers but one StoryCrate control tangible contains three additional push buttons on its upper side (the blue object in Figure 10). A wireless mouse inserted inside this tangible, connected to the three buttons, allows button presses to be transmitted to StoryCrate as left, right and middle mouse click events. These buttons provide a smaller granularity of interaction for the specific function related to the tangible – list selection. The ‘move clip’ function of the StoryCrate interface is performed by a bi-manual action operated by a pair of tangibles attached by a sprung cord. The retractable cord is located inside one of the two tangibles, pulling the tiles together when released. To provide additional textual input into StoryCrate, a physical keyboard is mounted above the display on the table-top surface. Entering information on the keyboard inputs directly into just one area of the interface situated just below the keyboard, and allows the crew to enter custom meta-data terms during the shoot.

To enter more complex and freeform data throughout the shoot, StoryCrate is equipped with an Anoto[22] pen and pad (see Figure 11). The pen connects via Bluetooth to StoryCrate and streams the users' drawings to StoryCrate. The pen lid is affixed to the top of the display surface and the pen is stored inside the lid when not in use and to save battery. Removing the pen from the lid auto-connects it to StoryCrate, and the pen streams all manipulations with the notepad live to the StoryCrate software. Anoto technology requires specially printed paper in order to track input, so StoryCrate contains an A6 pad of pre-printed paper mounted next to the pen dock. This pad includes a short description of how to operate the pen, and includes guidelines for various film frame sizes.

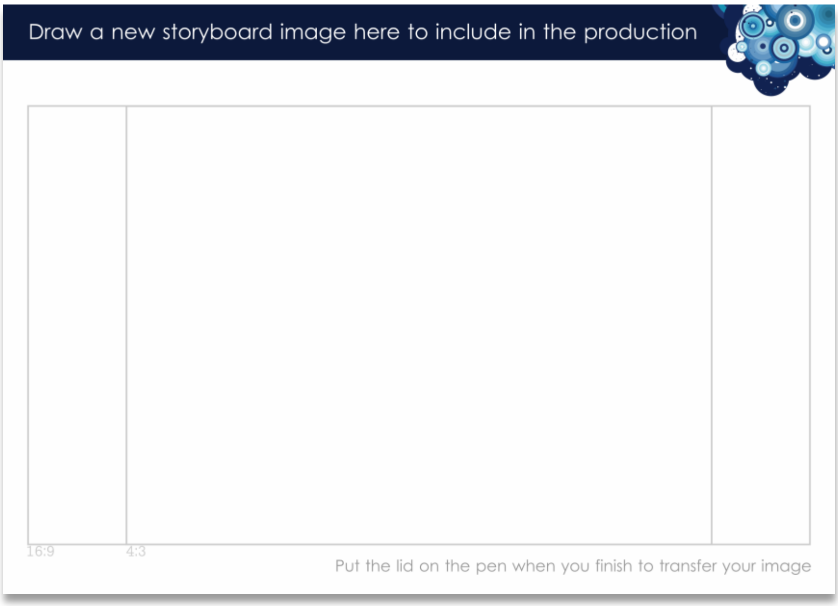



*Figure 11 Anoto Pad: For Entering User Content. Drawings on the pad are digitised and transmitted by Bluetooth to StoryCrate.*

### 3.7.5 Connectivity

StoryCrate is equipped with an Ethernet port, connected internally to an Ethernet router which provides a Wi-Fi access point for connecting to the two computers located within, primarily as an access point for debugging. On location, StoryCrate connects via Ethernet to INGEX[23], an open source tape-less recording system developed by the BBC. This Linux based system outputs video and meta-files located

[22] http://www.anoto.com/lng/en/pageTag/page:home/

[23] http://ingex.sourceforge.net/

on its own internal storage, which can be accessed using Secure Shell over the network. StoryCrate polls a remote directory on this recording system, downloading new thumbnail video clips and XML meta-data as they become available.

### *3.7.6 Software Infrastructure*

StoryCrate runs as a WPF (Windows Presentation Foundation) application in the Microsoft .NET 4 runtime. Code is written in C# and XAML (an XML mark-up language). Media playback is carried out using VLC (Video LAN Client) through a C# wrapper API. Communication with the Anoto pen is carried out using the Anoto .NET SDK. FFMpeg[24] is used for producing thumbnails of video clips in a thread and file safe manner.


*Figure 12 StoryCrate Software Architecture*

The StoryCrate software architecture consists of three layers (see Figure 12):

1. The Tangible Interaction Layer connects to both camera tracking services (ReacTiVision), and produces coherent and session based events for the rest of the application regarding tangible interaction with the interface. It combines the tracking data for the left and right areas of the screen, managing tangibles tracked on multiple cameras simultaneously, presenting the events in a normalized coordinate system relative to the StoryCrate display. At this level tangibles are matched against specific functions, and on-screen overlays are associated with specific tangible controls. This level also produces a visual overlay of tangible feedback to users of the interface. When a tangible is manipulated, circles (similar to ripples) move outward from the location of the interaction on the display, alerting users to peripheral movement or interaction by co-located users. This layer also manages the placement of preview displays on the correct monitors, and the display of the storyboard over both projected displays.

[24] http://ffmpeg.org/

2. The Data Management Layer manages all content represented in StoryCrate (Figure 13). It provides software interfaces, and implementations thereof for:

- A representation of the storyboard and editing decisions.
- Format conversion for import and export (e.g. Final Cut Pro XML)
- Media loading and thumbnail creation (e.g. video files, image files, text based meta-data)
- Anoto pen interaction
- Recording system connectivity, content retrieval and meta-data parsing (e.g. INGEX via SSH, Samba file store, USB Device)

The system is implemented in a plug-in style architecture so that new types of EDL[25], meta-data and video sources can be included by implementing appropriate interfaces.

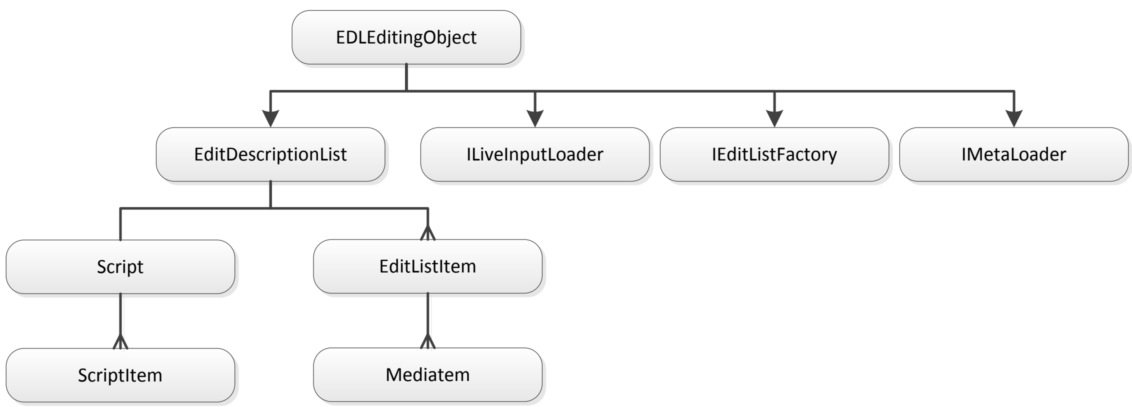



*Figure 13 Class Structure for Data Management Layer*

3. The Storyboard Manipulation layer provides the front-end user interaction and content representation for StoryCrate. This layer makes use of built in WPF animation features to provide a rich user experience. The UI is split into logical chunks related to functionality and location on the display and tangible events are passed directly to UI elements using Bubbled Routed Events.

### *3.7.7 Robust Design*

To facilitate a fast start up time from system failure, a watchdog script is implemented to restart the application on failure, and restart the computer on multiple consecutive

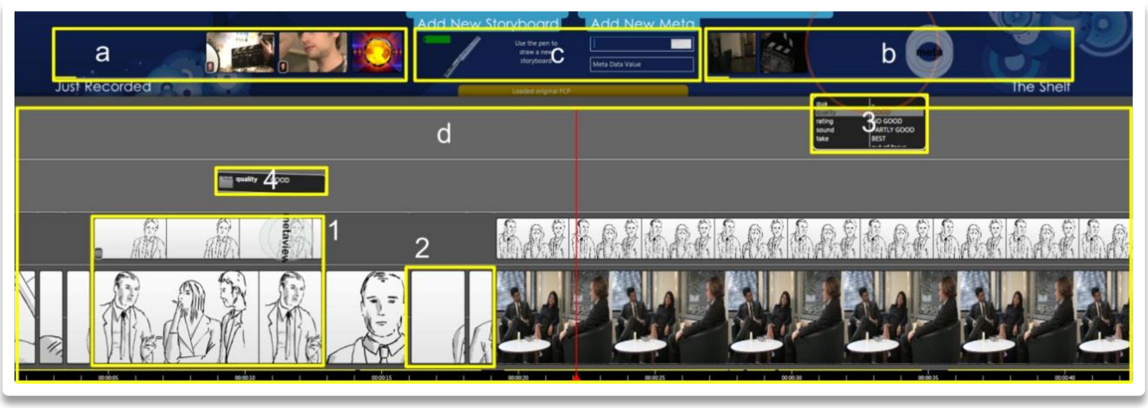
[25] Edit Description List – A machine readable description of the storyboard timeline.

failures. The software was designed to minimize boot time into a working StoryCrate interface by removing unnecessary services and tools in the underlying operating system. The StoryCrate application is also designed to die in a clean way, removing all menus and windows from the operating system on error, allowing the watchdog to detect a genuine software failure. Once a configuration is entered for a specific film shoot, subsequent restarts of the system auto-connect to the configured on-site recording systems to allow the crew to return to the last state as soon as possible and without further configuration. The current state of StoryCrate data is auto-saved every minute in a new file, which can be easily loaded on system failure. On restart, the last auto-save is automatically loaded for a rapid return to the current session. This load and save ability also provides the ability to maintain multiple versions of particular shoots, which can be loaded and saved independently.

## 3.8 Interaction Design

Crew interact with StoryCrate by manipulating tangible table-top controls. Upon first glance, StoryCrate presents a simplified multi-track non-linear editing environment similar to those found in consumer products such as iMovie[26]. The StoryCrate interface is divided into four areas (see (a), (b), (c) and (d) in (Figure 14)). Each of these areas is capable of displaying and arranging media items (images or videos) which appear as a static thumbnail. Within the timeline, media items are repeated horizontally to represent relative lengths of clips. During filming, clips from the recording system arrive in area (a) within ten seconds of a take being filmed and remain there until further action is taken. In this way, clips do not have to be processed by the crew in the order that they are shot. They can then be moved from here to either the timeline (d) or the shelf, a generic storage area (b), for later use. Providing areas of the interface that can be re-purposed encourages flexibility in the workflow, allowing the crew to delay decisions about incoming media for later, and to quickly organise clips using their own processes and criteria.

[26] http://www.apple.com/uk/ilife/imovie/




**Key**
a. Incoming footage from cameras, b. Storage area, c. Input feedback
1. Multiple takes of each shot, 2. Timeline layout of shots, 3. On-screen menus attached to Tangible controls, 4. Additional information about clips.

*Figure 14 StoryCrate Tabletop Interface*

At the start of the shoot, the timeline is loaded with a pre-prepared editing file which can include approximate lengths of clips, visual shot cues, audio dubbing, script and shot descriptions. During the shoot, these static images can be replaced with footage shot on location, creating a ‘rush’ edit of the final product incrementally throughout the shooting process. Of the two non-interactive monitors placed above the surface, the left displays single clip previews and is used during clip editing, whilst the right screen always displays the current output from the timeline play head. Display feedback elements associated with new content input are placed spatially close to the Anoto pen and keyboard in the centre of the display (c), to avoid ambiguity about where the feedback for these tools is located on the display.

Each tangible performs tasks related to a single specific function. This aids user learning of the interface and the communication of intent between users. Additionally, these controls are colour coded in two categories: tools which manipulate data and change content; tools which alter view and playback. Providing similar elements of functionality to a non-linear video editor, StoryCrate provides discrete functional elements for the following tasks, where each task is independent of another, allowing for complete flexibility in how users choose to operate it. These functional elements are represented by tangible controls and tools:

i. Editing Clips (clipping in and out points).
ii. Manipulating clips around the interface (move, delete, insert).
iii. Playback of the timeline.
iv. Looping preview playback of any clip.
v. Adding and viewing meta-data.
vi. Adding personalised content through drawing.
vii. View manipulation (zoom, scroll).

### *3.8.1 Moving, deleting, inserting and editing clips on the timeline*

Clips are moved around the display by placing one end of the *move control* on the clip to be moved, and the other end at the destination point. The control consists of two tangible objects joined by a sprung cord (see Figure 15). Lifting the destination end control moves the clip, and lifting the source end control cancels the operation. This control seamlessly performs inserts or moves depending on the destination location. By using both tangible and bi-manual controls, users' actions are externalized and other members of the team are more readily aware of changes. Clips are animated between positions both to avoid losing context while performing actions, and to support others' understanding of the context when viewed from a distance. Clips can be removed from the interface at any point by placing the *delete control* down on an item. After a two second timeout, the clip is removed when the control is lifted. This prevents accidental deletions and allows other users to intervene in critical actions.


*Figure 15 Add, Delete and Move Media Tangible*

All clips that are added explicitly or imported automatically from the recording system are kept on the local system in case they are needed in the future. Clips can be added from this archive by using the *add clip control,* which displays a half-circle list of possible clips when placed down. Users can scroll through this list by rotating the control, and can import a clip by centring the list on the clip and lifting the control off the surface. The selected clip is then added to the shelf area for use.

### 3.8.2 Playback of both the timeline and individual clips

Clips located on the timeline (d) are played back sequentially using the *play head control*, which when placed on the timeline represents the current playback position, with the timeline scrolling horizontally underneath it. When rotated, it can also be used to scroll or scrub through the timeline. The full resolution output is displayed on the right hand vertical monitor (see Figure 1), which is visible from a distance to all team members. Clips can also be looped on the left-hand monitor by placing the *preview control* on a clip. By placing the *preview control* to the right of the *play head control* spatially, previews of future clips are automatic.

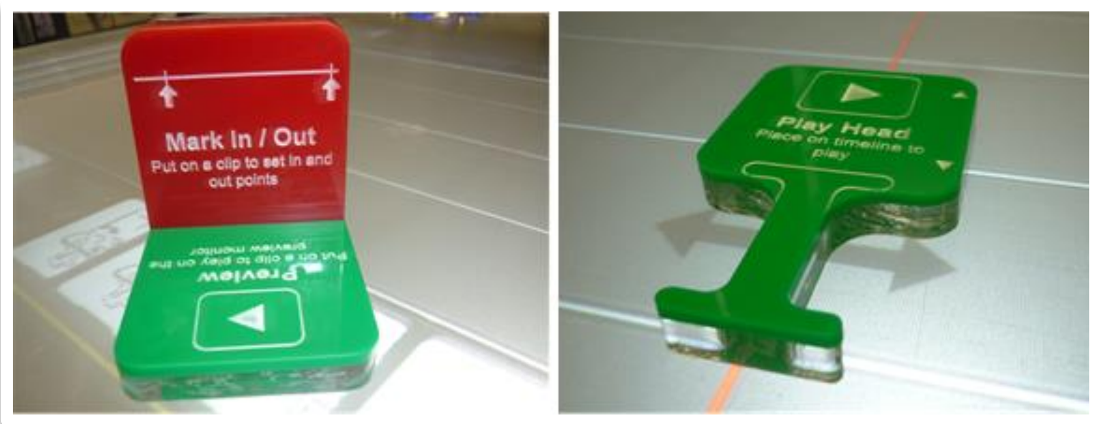



*Figure 16 Play Head and Preview Controls*

### 3.8.3 Selecting in- and out-points on clips

Depending on the director, footage may arrive in large sections with multiple takes within a single block of video. To segment these and cut out useful shots, the *clipping control* is used (Figure 5). This controls the left-hand monitor and is physically attached, and oriented perpendicular to the *preview control* so that they cannot be placed down simultaneously, thereby enforcing an important functional constraint within the tangible control. When placed on a clip it takes over the entire timeline display, and controls for the in-point and the out-point are used to place accurate markers within the clip. This forces all users to collaborate on one specific task, while also allowing a high-resolution positioning. When the operation is complete, the *clipping control* is removed and the clip is updated. Multiple takes of the same shot can be stacked on top of each other, as shown in (1) in Figure 4, by using the *take selector control* to select the clip to playback within the main sequence.


*Figure 17 Clipping, In, Out and Take Selector Control*

### 3.8.4 Adding and Viewing Textual Metadata

Metadata takes the form of text key-value pairs and can be added by placing the *add meta control* onto a clip (see (3) in Figure 4). A list is displayed next to the control and extra buttons located on the control allow the user to navigate the list and select the required metadata tag (Figure 18). This fine-grained list control is implemented using physical contextual buttons as more than one parameter (provided by rotation) is required to navigate the list. Metadata presence is displayed as an icon on a clip, and in more detail by placing the *meta-view control* on the Media Tile (see (4) in Figure 4).

### 3.8.5 Adding new hand-drawn storyboard content

An important feature of StoryCrate is its facility to allow the addition of new storyboard content *during* a shoot, allowing users to explore different creative avenues. This is accomplished using a digital Anoto pen (see (c) in Figure 4) and drawing a new still frame on the pad provided. When docked, this image appears immediately as a clip on the shelf (see (b) in Figure 4) like other media. New metadata pairs can be added by typing directly on the keyboard (see (c) in Figure 4), and these are directly available to the *add meta control*. These text and freehand drawing capabilities are the only uses for the keyboard and Anoto pen, which prevents ambiguity regarding their functionality, promotes the visibility of these actions, and facilitates faster and more spontaneous input. Potential conflicts during use, such as two users simultaneously wanting to add metadata is negotiated by providing only one physical control for each action. This requires users to negotiate for functionality, forcing externalization of their intentions. When a tangible control is manipulated by a user it displays a subtle expanding circle animation emanating from the centre of the object. Similarly, when the software moves thumbnails beneath an object on the surface a smaller visual indication is made around all tangible objects placed on the display. These promote users' direct and peripheral awareness that the interface is responding to their input and that of others. When the shoot is complete, StoryCrate exports the timeline back into an XML file, which can be directly imported into a video editing system, retaining all metadata, editing and take information. An editor can use this file directly at a later date, using it as a starting point for the editing process.


*Figure 18 Add Meta-Data Control*

### 3.9 Conclusion

In this chapter I described StoryCrate, a prototype tangible, table-top interface for deploying on-location to film shoots to support creativity within production teams. StoryCrate uses a picture timeline storyboard as a shared data representation to facilitate awareness amongst the crew in a collocated, physically central system, enabling them to engage with content throughout the shoot. It is designed to facilitate creative practice by providing individual tools that enable the crew to collectively produce *in-situ* 'rush' (rough example) edits alongside their existing professional roles. In this chapter I defined these elements of creativity in terms of team production and the practices identified that drive creative workflows. I subsequently discussed the design rationale and my response to these challenges, and described the prototype of StoryCrate in detail. In Chapter 4 I discuss the deployment of StoryCrate and open a discussion into the implications of my design decisions on the creative process of film making and the benefits of tangible, table-top collaborative interactive displays in situated TV production.

# Chapter 4. On-Location Production

*WITH STORYCRATE*

## 4.1 Introduction

This chapter presents a contextual analysis of StoryCrate drawn from data collected and analysed during the filming of a three-minute TV short, commissioned by the BBC for a study of StoryCrate using existing staff and procedures. Working with field materials such as first person accounts, interviews and observational data gathered in a focused rapid ethnography, I present a narrative of the deployment, centring on StoryCrate. Drawing inspiration from Orr's 'war stories' of photocopier technicians (Orr, 1986), I specifically present a narrative account of the crew's experiences during the shoot, interacting with and through StoryCrate. From this I come to illustrate the StoryCrate's impact on creative workflow within situated media production teams.

With this narrative lens, I illustrate three stages of evaluation, performing a detailed analysis of the StoryCrate deployment and discussing in depth the affordances of such a device in a TV production context. I highlight key issues around democratization and creative workflows, and consider re-applying design elements of StoryCrate to the wider production domain, presenting a design critique and recommendations for future designs.

## 4.2 The Deployment

A multitude of situational factors creates a uniquely challenging environment for production teams. These teams have learnt to thrive in such unpredictable environments, with the result that team members perform specific skilled roles whilst maintaining relationships of trust and mutual understanding that minimize the need for complex and detailed communication between team members. Environmental and temporal factors are foremost in the planning of such shoots, so lab-based studies are unlikely to be able to predict how a real production team will use and adapt to new technology when it is deployed 'in the wild', as by their nature these factors cannot be replicated with the same compound effect on the workflow. Therefore, I sought to deploy StoryCrate in an in-the-wild (genuine) TV shoot to evaluate how a professional crew would integrate it to their environment and workflow. During the planning of this shoot, it was kept to the fore that StoryCrate was not designed to directly perturb existing practices by forcing new production workflows, but to facilitate the crew within their own roles, supporting their emergent engagement with creative practice. As such, the TV shoot was planned using existing production procedures up to the point of shooting on location.

### *4.2.1 Deployment In-the-Wild*

In “Why it's worth the hassle”, Rogers suggests that ubiquitous computing interventions are difficult to evaluate due to their inherent specificity in context of use, and that traditional lab-based studies fail to capture the complexities and richness of each specific domain (Yvonne Rogers et al., 2007). Johnson and Rogers promote the values of in-the-wild studies, describing the unique contribution to the field that can be made when a researcher participates in the study as a member of the domain, supporting a detailed understanding of the domain, but also building relationships with the ‘real’ users (Johnson & Rogers, 2012). These relationships can be managed to facilitate self-reflection of both the end-users and the researchers during the deployment process to gain insight into the intervention. Of the beneficial facets acknowledged by Johnson and Rogers, the impact of hierarchical authority is important to consider within situated production teams. By framing the researcher as an equal amongst the production team, but without proposing the replacement of existing team roles, a rapport can be established between the crew and the researcher. This rapport softens animosity towards the introduction of new technology, as the team members acknowledge that the researcher has an empathic understanding of their roles, along with an understanding of the technology.

As well as the benefits of in-the-wild deployment, a number of challenges exist (Brown, Reeves, & Sherwood, 2011). Of these, Brown *et al.* propose three key factors which impact on deployments that are characterized by situational factors analogous with media production:

i) *Demand characteristics* describe the notion that participants may react in a trial with an expectation of what the researcher is looking for. By being aware of this, I can frame out deployment in a manner that removes the need for a participant to behave in a measured response to my research goals and still gain useful data.

ii) *Lead participants* are individuals within the participant group whose interaction with the deployed technology is key to understanding its use in the environment. In some cases, researchers will become participants due to their own knowledge of the domain, or skill in operating related technology. This may skew the results, as 'unexpected behaviour' may not emerge from participants who have been effectively trained in the correct way to use a device through observing the researcher. Conversely, this can be an advantage, and involve the training of participants in use of technology before being left on their own, reducing the learning curve for technology designed for expert users.

iii) *Trial designs* that do not consider the possibility of different groups of participants can lead to wide ranging results in a field trial. This can be due to the design of the study, and because group dynamics and pure chance can change the way participants react to the study, and these should be considered as significant factors in planning deployments.

Deploying a prototype for in-the-wild deployment necessitates creating a robust system (digitally and mechanically). Although high-fidelity prototyping has been shown to be an effective approach it is not employed as widely in interaction design as agile programming is for systems design. One notable obstacle to these prototype deployments in a domain with expert users such as television production is the trust that crew have in their own equipment. Crew members come to rely on specific functionality and become used to idiosyncrasies of their own equipment, knowing possible pitfalls and fault points. They are also acutely aware of the long lead-in times of learning to use new equipment effectively, and the inevitable process of discovering foibles in new equipment.

### 4.2.2 The Scenario

To initiate the production process that led to the TV shoot, a local director was commissioned by the BBC to write and direct a three-minute TV short (of his own choosing). This script was produced and edited with regard to practical considerations such as cost and location, specifying two to four characters (due to budget limitations) and four distinct scenes. These requirements are in line with constraints set by real-world productions. In the next stage of the process, the director worked with a visual artist to develop a pictorial storyboard including camera angles and shots. These image frames were combined with the script and rough timings gained from vocal dubbing into a Final Cut Pro project, and imported into StoryCrate before the shoot began. These initial stages of production took approximately three months.

The shoot itself was planned for a three-day period, which consisted of a half-day training session followed by a two-day film shoot as follows:

| | Morning | Afternoon |
|---|---|---|
| **Day 1** | StoryCrate Training and Team introductions | [research team meeting] |
| **Day 2** | Scene 1 (with StoryCrate) | Scene 2 (with paper storyboard) |
| **Day 3** | Scene 3 (no additional resources) | Scene 4 (with StoryCrate) |

**Training**: An initial half-day training session introduced the crew to the basic operation of StoryCrate, and gave an opportunity to introduce both the research and production teams. A short video was presented to describe each functional element of StoryCrate, followed by a verbal presentation and scripted tutorial by a collaborator who was not involved in the technical development. I was careful to avoid leading the crew members as regards my anticipated scenarios of use (hence not describing the system myself). Over the rest of the morning, the crew were tasked with creating thirty-second clips introducing themselves, rotating production roles intermittently throughout. Each member was encouraged to try a variety of tools and functions in StoryCrate during this session, as well as appreciating the other roles and responsibilities within the team. Individual elements of StoryCrate were described to the team during this training phase, but no specific guidance was given on how they should best appropriate tools for their own workflow.

**Shoot**: The crew was asked to produce the short film within their normal working practices, appropriating StoryCrate when it was relevant and beneficial to the tasks at hand. Prior to the shoot, the Director was briefed only on the overall functionality of StoryCrate, and having arrived on location he was encouraged to integrate StoryCrate in his existing workflow, fitting around the team as appropriate to how his traditional workflow was managed.

The two-day shoot was split into four distinct phases of half a day, with the shooting of one scene of the script in each phase. At the start of each session, the crew received a briefing outlining the technology they had at their disposal (combinations of paper storyboard, StoryCrate and shoot order), and the Director outlined the scene they were to shoot. From that point onwards, all organizational responsibility was handed off to the production team themselves (managed through the director). Although the film shoot was managed in a traditional manner, with the Director taking operational control, we explicitly encouraged the use of StoryCrate. The director was briefed to use the system in a way that facilitated the shoot, but also to be open to changes in team working practices. Importantly, the briefing emphasized the importance of concentrating on quality of product (rather than completion within the deadline).

The goal of the study was to understand the impact of StoryCrate on the practices of this particular production team. Furthermore, because storyboards are not in common use (even in paper form), it was important to distinguish between team interaction deriving from the storyboard, and interactions arising from StoryCrate. I therefore only allowed the crew to use StoryCrate for the first and last session, used a printed paper storyboard for the second session, and no storyboard at all for the third session.

### *4.2.3 The Team*

A crew of seven full-time professionals were hired for the shoot using existing BBC recruitment protocols to fulfil their normal production roles (Director, Camera Operator, Sound Recordist, Script Supervisor/Assistant Director, Runner and Lighting Designer). They were joined by four actors and a makeup artist, in line with a standard BBC TV shoot. Some of the team had past experience of working together but the majority were unknown to each other. Figure 19 shows the variation to a traditional team structure (see Figure 5) which was organised by the director as his preferred method of working.

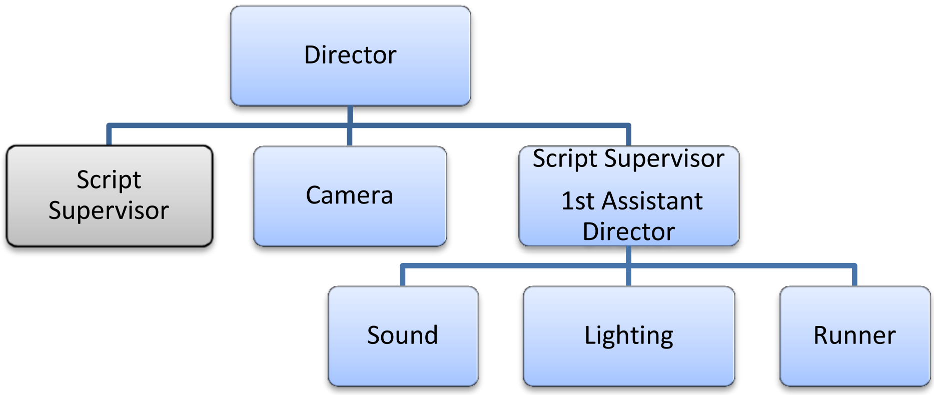



*Figure 19 Deployment Team Structure*

### 4.2.4 Observation Strategy

My methods for generating empirical materials about the deployment of StoryCrate were based on Randall *et al.*'s idea of fieldwork-for-design (Randall & Rouncefield, 2010). My understanding of the field setting was based on a prior ethnographically-informed study of TV production (Fletcher, Kirby, & Cunningham, 2006) and my own experiential understanding as production crew member. I specifically conducted a targeted 'rapid ethnography' (Millen, 2000) of StoryCrate being used *in situ* and in-line with 'fieldwork-for-design' approaches; this ethnographic work was conducted by myself and an interdisciplinary team of collaborators. Like Tripathi *et al*. (Tripathi & Burleson, 2012), I saw the benefit of investigating crew creativity in-the-wild, but rather than critically document and 'measure' features of creativity, I used ethnographic praxis to understand the sociality of StoryCrate's accountable use. This observational approach involved placing observer-documenter pairs at physically disparate points throughout the shoot environment to capture a range of interaction with StoryCrate.

This distributed approach allowed me to draw out a rich and diverse set of data consisting of focused observations and an overview of group and interpersonal interactions both around StoryCrate and in the rest of the shoot location. The ethnographers were briefed with suggested thematic codes to use while observing prior to the deployment, and notes were time stamped throughout. In the outer observation space, a further observer filmed and documented the study process as a whole. Figure 20 summarizes the full set of participants and the members of the film crew and the actors during the shoot.

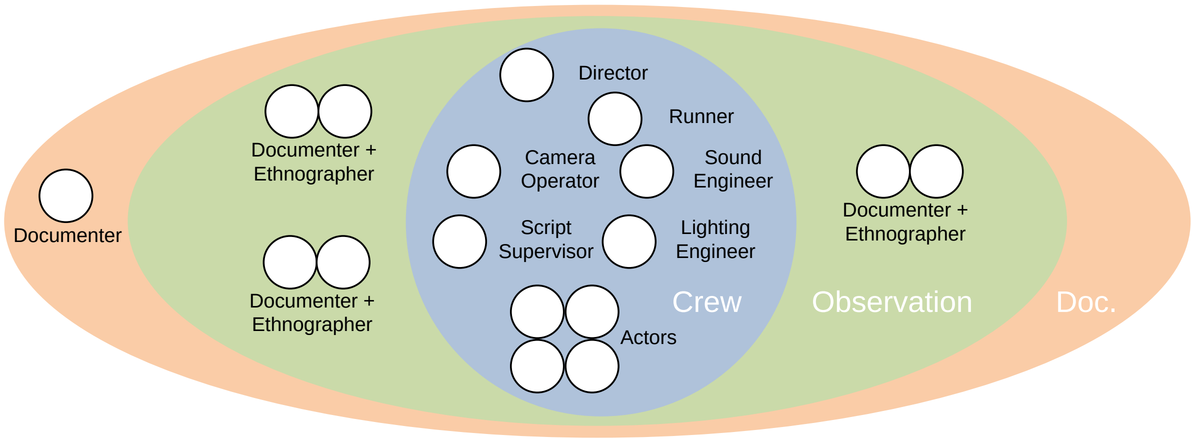



*Figure 20 Observation Strategy*

In addition to observations, interviews were conducted with each of the crew members before and directly after each phase to capture their immediate reactions. These interviews were semi-structured, with interviewers having the freedom to explore ad-hoc topics when appropriate. Questions were based upon conventional HCI evaluation methods (exploring issues such as utility, ease of use and satisfaction) (Wickens, Lee, Liu, & Gordon-Becker, 2003) but were also adapted to explore important qualities of production (such as creativity, role-taking and ownership of content), and key functionality of StoryCrate. Emerging themes from earlier interviews were incorporated into later ones where appropriate.

The resulting data-set consisted of:

*i)* 5 Interviews from each of the 6 crew members;

*ii)* observational video footage from 3 cameras;

*iii)* time stamped observation notes from 3 observers.

This was supported by additional resources including: group interviews with various sub-groups of actors, 'tramline' notes from the Script Supervisor's own documentation, anecdotal video and observational evidence from both research staff and participating crew members after the event, and the resulting edited film and source footage.

## 4.3 The Anticipated Workflow

StoryCrate was designed to provide tools that could be appropriated by the production crew in multiple configurations. Individual tools were designed based on activities performed as part of a traditional TV production workflow, such as editing and playback, but designed not to encourage the crew into particular workflows such as they would use in an editing suite. However, to set up an observational strategy that would result in succinct and meaningful data, I developed three use cases that reflect my expectations about how StoryCrate could potentially facilitate creative practice during a TV shoot. These were used as an initial expectation for developing the observation strategy. I did not inform the production team of my expectations during the study, rather I used these expectations to focus the observational resources during the deployment. I paid particular attention to observing whether aspects of these cases emerged, allowing us to update my observation strategy incrementally in response to the production team's behaviour. In all these cases, I expected shots to be inserted into the storyboard during the shoot, and that these would be edited in some form, thereby creating a rush edit by the end of the active shoot, that can be reviewed either immediately or at a later stage.

### *4.3.1 Clip Review*

In this scenario, StoryCrate would be primarily used for clip review. The director would maintain control over it, and use it during breaks in the shoot schedule to explain current progress, show the rest of the crew what they had produced and how content is progressing. Viewing playback of clips rapidly after filming enables the crew and actors to engage with content and drive their creative input in relation to the director's vision and specific feedback. Clips from the cameras are batch processed into the storyboard at intervals (not every time a clip is shot) by a member of the production team and only shown to actors and the rest of the crew when the director is happy with a complete section of the storyboard.

### *4.3.2 Context Explanation*

StoryCrate would be updated in response to every clip that is shot. The director would explain shot context and ideas using StoryCrate at regular intervals to engage the crew with the current task. Specific shot characteristics could be demonstrated and continuity aspects would also be considered during these discussions. The storyboard would be incrementally updated using real footage and could be reviewed by any crew or cast member on set at any time, supporting each crew member's creative role through individual interaction with the content.

### *4.3.3 Logging*

StoryCrate would be used by all members of the crew to log shots and add metadata pertaining to the editing phase of production, as well as imminent production tasks. The director would not have direct interaction with StoryCrate, but would allow its use as a logging tool for monitoring shoot progress and recording meta-data by the rest of the crew. Through meta-data creation and the validation of shots through post-playback, the crew would be satisfied in their creative efforts and the transfer of decisions to later stages of production.

*Figure 21 StoryCrate on Location, Operated by the Runner*

## 4.4 The Account

To provide a rich data source to contextualize crew experience during the deployment, a narrative account of the three days is presented below. We observed the crew transitioning through many stages of interaction with StoryCrate over the length of the deployment. In such a complex environment, I did not wish to miss contextual understanding gained from a knowledge of the wider team context throughout the deployment. By presenting this data as a narrative account, I describe the overview of the scenario for context with the ability to identify key areas of interest through how the crew interact with each other and the system. This is an abridged and summarized account taken from observational and video data, and is presented to temporally and contextually ground further analysis:

### 4.4.1 Day 1, Training

1 The crew was instructed to meet at an office in a large city in the South East of England. Each crew member was recruited to perform a specific production role. The Director, Cameraman and Soundman had worked together previously; the rest of the crew were new to one another. The focus of the narrative, the Runner, had a role consisting of odd jobs, helping out and performing minor unskilled tasks when required.

2 The crew was given a brief presentation on the intended structure of the deployment, a functional overview of the StoryCrate, and a guided hands-on session with the device. At this early stage, the Lighting Engineer, a professional with over 30 years' experience, politely refused to use the new technology, stating that he was hired to perform a specific role, and that he wished to perform it to the best of his abilities without extra technology making him feel uncomfortable. He stayed in the session to get to know the rest of the crew without direct involvement in the training.

3 For the remainder of the morning, the crew was tasked with shooting a simple video, using a pre-prepared storyboard already loaded onto the crate. During this mock shoot, crew members were encouraged to switch roles and experience StoryCrate operation, being prompted to use all functions.

4 At this point it was clear to observers that the Runner had picked up the operation of StoryCrate rapidly, and was the most proficient at performing a wide variety of functions.

5 As part of this training, the Director was given time to introduce himself and explain his style of working to the crew. More specific working patterns were outlined, including the Script Supervisor also doubling as the Assistant Director. As part of this, the Director stated that although he wanted to encourage use of the StoryCrate, making quality content unquestionably came first.

### 4.4.2 Day 2, Morning: Using StoryCrate

6 The first day of shooting started. In discussion with the Script Supervisor, the Director felt that they would benefit from StoryCrate more if it had an assigned operator. As the crew set up, the Director informed the Runner that he had been given the newly created StoryCrate 'Operator' role.

7 Once equipment had been set up, the Director sent the Runner on several errands (as was typical practice). The Director gathered his inner group of Cameraman and Script Supervisor around the StoryCrate and explained his vision for the morning's shoot. He used playback tools on StoryCrate to show the pre-prepared storyboard. This was the first time that the practicalities of the script, such as camera positions and props, had been discussed. They also decided how best to manage the use of StoryCrate and appropriate it into their workflow.

8 When the Runner returned, the Script Supervisor outlined the workflow they envisioned for use of StoryCrate, and how his task would be to reactively update

content as it was shot, adding meta-information when apparent to the Script Supervisor.

9 Filming commenced, shots were filmed, and the storyboard on StoryCrate was filled with clips. Meta-data from the Script Supervisor at this point only consisted of good/bad shot indicators. During this time, the Director required a Clapperboard operator (a tool used to sync audio and video, and record information about clips), but rather than re-purpose the Runner, who was busy updating StoryCrate, he himself took up this task.

10 Confidence was now building in the crew as they worked together, and the Runner had taken a more active role in meta-data decisions, inputting information without any input from the Script Supervisor. He was now making decisions about where the shots fit in the storyboard, and was noticing minor issues such as ‘boom in shot’, feeding this information back to the Script Supervisor who would then call for re-shoots.

11 As less active input was required from the Director to keep the crew working, he then felt able to start using features of StoryCrate himself. He wanted to play back a specific piece of footage in order to check for continuity against the current shot. Although he understood this functionality existed, he requested that the Runner bring up this piece of footage for him.

12 Whilst operating StoryCrate, the Runner sat on a chair directly in front of the device. This meant he was unable to reach the Tangible storage area at the top of StoryCrate without standing, so he started to place the Tangibles on their side (to stop them being tracked) on the display surface near to where he last used them, for quick access. When the surface became cluttered he arranged the control-widgets on his legs.

13 By half-way through the morning, the crew had shot a large amount of content. Two takes of the same scene from different camera angles then needed to be compared by the Director. The Runner suggested re-purposing StoryCrate’s take-switching tool to place clips in-situ. He quickly did this, and the others gathered around to view.

14 The Runner was now becoming viewed as ‘part of’ StoryCrate (invoking a common on-set conflation between person and equipment they operate e.g. cameras or lights), and when the Script Supervisor brought the Director to playback clips, they both leant over the Runner, and he became part of the discussion without explicit invitation, due to his proximity.

15 As the shoot continued the Runner demonstrated his ability to use the StoryCrate for spotting continuity errors. Whilst the rest of the crew set up for shots, he would re-play clips and bring issues he identified to the Script Supervisor’s attention, who would then alert the Director.

16 Late in the morning the Runner was again sent on errands outside. The Director, demonstrating confidence that the crew was working together smoothly, started manipulating StoryCrate himself. During filming, he lingered at StoryCrate with the Script Supervisor, checking shots that had already been placed on the storyboard by the Runner.

17 New shots stacked up ready for processing; on returning the Runner found that StoryCrate had been minimally maintained, with most shots not added or having meta-data applied. Now proficient, he quickly updated all the content. During this period,

the Lighting Engineer observed over the Runner's shoulder, in order to check lighting continuity. The group then broke for lunch.

### 4.4.3 Day 2, Afternoon: Paper Storyboards, No StoryCrate

18 The crew met back at the same indoor location. For this session, they were provided with a printed copy of the scene's pre-prepared storyboard, which was stuck, in sequence, on the wall. There was no access to the StoryCrate. The Runner was assigned back to traditional tasks such as holding lights, moving props and calling actors to set. He also became the Clapper Board Operator, a role that the Director had performed in the morning.

19 After an initial overview planning session with the Director, Script Supervisor and Camera Operator, using the printed storyboards as a reference point, the Director chose not to use the storyboards again; so many changes were made during the previous filming session that the storyboard, became incorrect, and was seen as a hindrance.

20 Although the crew had no access to StoryCrate during this period, they re-purposed the tapeless recording system to allow themselves to playback clips that had been shot within the session. This functionality was only partially available in the recording system, and was not initially advertised to the crew. Finding they missed this feature in StoryCrate, they insisted on using this feature.

21 During this session, a particular type of shot was attempted, involving two shots from opposite angles. Whilst attempting this, the Director became extremely annoyed that he did not have the capabilities of the StoryCrate in order to match both shot angles against each other to check that the camera angles and lighting were correct.

### 4.4.4 Day 3, Morning: Traditional Shoot, No StoryCrate

22 To start the last day of filming, the crew met at a nearby outdoor location. The Runner was asked to ensure that the set was clear of non-crew personnel and vehicles, as well as holding lighting reflectors and shades when required.

23 The only unusual piece of equipment onset in this session was a small video monitor attached to the live camera feed. This was requested by the Script Supervisor as otherwise there was no easy way to play back clips in order to check for continuity. The Director and Script Supervisor reviewed clips on this display after each shot before continuing.

### 4.4.5 Day 3, Afternoon: Using StoryCrate

24 Back at the internal location for the afternoon, the crew was again given access to StoryCrate. Whilst most of the crew was at lunch, the Director and Script Supervisor requested that footage from the two previous sessions be loaded into StoryCrate so that they could view all the footage together, filling in gaps in the storyboard. This action contextualized the content created thus far, allowing them to spot the missing shots that still needed to be filmed.

25 The crew returned from lunch to shoot another scene. The Runner returned to his role as StoryCrate Operator, and the Director used him as a tool through which to control playback and show the Cameraman his vision. He used the Anoto pen to explain additional content and camera angles for this scene.

26 During a long makeup break, the Runner sat at StoryCrate whilst the Director requested for clips to be played back. As the shoot continued, rather than give broad indications of meta-data for the Runner to interpret, the Script Supervisor specified meta-data descriptions.

27 In one instance, the cameraman was aligning a camera, physically distant from StoryCrate. For continuity, the Director requested that a line of sight be made between the camera and StoryCrate, and that the corresponding clip be played in order for the camera to be matched against it. The Runner played the clip, but not directly as part of the Director's and Cameraman's discussion.

28 Whilst the Runner was sent out on more errands, the Cameraman requested playback of a clip. The Director, Script Supervisor and Cameraman collaboratively found and played the clip. They observably took much longer than the Runner.

29 During a long makeup break, the Director took the opportunity to sit at the StoryCrate and use it himself, engaging in some personal 'creative' time, exploring the shot clips. The Runner returned to find the Director in the operator chair, preoccupied by planning with the Script Supervisor. The Runner then had a dilemma; his primary role was to sit in the chair and maintain the StoryCrate but he was now prevented from doing so.

30 Whilst seated, the Director attempted to insert a clip into the storyboard, a feature with which he was not proficient. The Runner was quick to his aid, using the opportunity to retain some Tangible controls. As soon as the Director moved from the chair, the Runner sat back down and reasserted himself as the operator.

31 Later, the Director gathered members of the crew around StoryCrate, demonstrating shoot progress. The Director observably felt proficient at operating playback, and asked the Runner to move so that he could sit and operate StoryCrate. The Runner stood to the side, and gave technical support as needed. During this period, the gathered crew reached across and manipulated the interface.

32 By half way through the afternoon, the crew was shooting and the Runner reassumed the role of StoryCrate operator.

33 The Runner was sent on an errand once more and the Director took his place, using StoryCrate to plan remaining shots with the Script Supervisor and Cameraman. Other members of the crew were also now observably confident in performing StoryCrate's playback and insertion features and they used the drawing tools to creatively plan final shots. The Runner was no longer needed for technical support and was sent on more errands.

34 The Runner later regained the role of Operator, and actively inserted himself into the workflow by spotting continuity errors in clips, alerting the Script Supervisor.

35 As the shoot neared its conclusion the Director went to StoryCrate to review content; making sure they had shot enough for editing. It was clearly his role as Director to do this, and the Runner reluctantly stepped aside again. For a few awkward moments, the Director asked for the Runner's assistance. When the Director stepped away for a moment, the Runner took over immediately, applying meta-data and inserting shots.

36 At the end of the shoot the crew packed equipment down. The Director approached StoryCrate, looking as if he would use it, but unable to locate another crew member who had sufficient experience in operating it, he chose instead to review clips on the tapeless recording system via its operator.

## 4.5 Analysis Strategy

The narrative account of the TV shoot centres around the interaction of crew members with StoryCrate. As such, it represents a cross section of the entire shoot process, allowing us to chronologically frame important moments of the crew's experience when drawn out in a three-tiered analysis comprising: (i) interview analysis, (ii) group analysis and (iii) video analysis. Each analysis tier expounds a valuable reading of the data in relation to key issues, through first diverging themes into wider contexts and then converging towards a clearer interpretation of the data (Hall & Rist, 1999). After each stage of analysis, memos were incrementally refined for each resulting theme, describing key features and giving supporting examples (Birks, Chapman, & Francis, 2008). These form the basis of my discussion.

### *4.5.1 Interview Analysis*

As an initial analysis step I studied interviews conducted with the crew due to their comparable structure and chronological sequencing. The shoot Director had been involved in the entire production process from conception and was most aware of the team dynamics and creative content manipulation that occurred on set. Having the role of writer and director also gave him the greatest stake in the successful creative output of the production, and made him a logical starting point with which to focus an analysis based around the crew's experience of the shoot. By using this knowledgeable source alongside the narrative account I could provide a functional baseline from which to compare the rest of the interview data. I produced a thematic analysis of the Director's interviews using initial codes drawn from the original interview questions (Braun & Clarke, 2006). Following on from these initial themes, I coded the remaining crew interviews, gathering data that both supported and contrasted with themes collected from the Director's coding.

When interpreting interview data from such a small set of individuals, it can be difficult to contextualize the experience and actions of a single individual within the group. As such, it was important to ground these initial themes of interest in relation to the wider crew experience and deployment with data outside of their own personal experiential reports.

### *4.5.2 Group Analysis*

To perform a validation of the themes gained from analysing the interview data and develop their nuances, a one-day analysis workshop was organised. Participating in the workshop were seven researchers of various levels of experience; three had been involved in the StoryCrate deployment and four had related backgrounds and experience in qualitative analysis. By providing data to the group that was unbiased by analysis codes from the initial evaluation (interview transcripts, video data and their own accounts of the event), and taking into account an experiential reading (J. A. Smith, 2007) of crew interaction during the deployment, the crew's own description of the shoot was contrasted with that of a third party interpretation of the event. This allowed the analysis team to approach the scenario from each crew member's perspective independently, with pairs of researchers analysing a crew member individually. This analysis was split into four distinct phases:

i) An overview of the StoryCrate technology, deployment and background concepts.

ii) Small groups working to thematically code a particular crew member's interviews.

iii) A presentation from each group on their crew member's experience of the shoot and how this related to StoryCrate and the creative output of the team.

iv) A discussion of each crew member, and forming a higher-level group of themes with which to direct further analysis, followed by the viewing of key sections of observational video footage through which the discussion continued.

### *4.5.3 Video Analysis*

The first two stages of my analysis had been based on a reading of the available data from the crew's perspective. Although valuable, this lacked a wider understanding of how the collective group operated as a single creative unit during the shoot. To contextualize personal accounts within the wider deployment I turned to objective video footage and notes taken by the observational researcher team during the deployment (Iversen, 1991). I took two distinct routes through this large amount of observational data:

i) Finding examples of specific situations highlighted in crew interviews to contextualise the crew members' experiences within the current group context and state.

ii) Performing a basic interaction analysis of the key interactions between the crew and StoryCrate (Jordan & Henderson, 1995).

These two processes resulted in a deeper understanding of the complex interpersonal relationships between crew members which started to emerge during the second phase of analysis, and when combined with the interview themes highlighted the network of relationships and actions around StoryCrate during key moments.

## 4.6 Resulting Themes

Three major themes emerged from my reading of the available data. Each of these is described in detail using vignettes of user experience to expound their key properties. Although these themes became apparent after the initial stage of analysis, they were subsequently refined through later phases of analysis to present quintessential illustrations of these themes, with associated quotes from interviews.

### *4.6.1 StoryCrate as a Shared Representation*

Used primarily by the Runner on behalf of other crew members, the clip playback tool was the most used function of StoryCrate, and was used after most takes to review footage. Used in conjunction with the storyboard, it allowed small sequences of clips to be arranged and played back and shots could be played back in the order they might be edited. Although StoryCrate allowed for much longer sequences to be constructed (e.g. an entire scene), only two or three shots were viewed in sequence.

**Reference Tool:** StoryCrate was perceived as a centralized reference point, primarily to match previously shot clips against current camera positioning (see paragraph 13 in the narrative account). Distinct from continuity checking (reviewing two existing pieces of footage), StoryCrate was used for matching a shot currently being filmed against both the storyboard tile that represented it, and clips it would be sequenced with, a feature missed when StoryCrate was unavailable (see 21). In this moment, without access to StoryCrate the crew found planning a complex shot difficult, without the facility to visualize it pictorially. The ability to utilize the Runner from across the room to plan this shot using StoryCrate may have saved them having to re-rig the scene, and increased confidence that this was producing a good result. By incrementally adding clips, a more accurate and reliable base of footage existed for checking continuity against, which should have enabled more accurate and thorough continuity checking and avoided un-necessary reshooting.

Quickly having an overview of what had been shot and what was remaining was valued, especially by the Script Supervisor and the Director:

> *"It is very helpful in terms of quickly assessing what information you've done… It made a complete difference"- Director*

The timeline, showing blank spaces or storyboard images was used as a quick visual check list, illustrating the duration of remaining footage and not just the number of shots. This reference was then explicitly shared with the crew when time was running out, and particular shots were not possible (see 33-36):

> *"It was good to have something to point at, reference, a way of saying 'you haven't got this'"- Script Supervisor*

Although StoryCrate was designed with a storyboard as its central representation of the shoot, this was not the only available method with which to present this data in a meaningful way. After abandoning the pre-prepared storyboard (see 19), the Director's self-reflection suggests that even an incorrect storyboard was helpful as a starting point (and reference during shooting) when explaining his vision to the crew. However, as the Runner had resumed a traditional role, he was not a participant in these discussions. The storyboard representation proved useful for helping the Director to transfer his creative vision to other crew members, demonstrated in two key instances: planning the session's shoot (see 7), and playback of material not shot with StoryCrate (see 24).

**Peripheral Awareness:** StoryCrate displays large sections of the storyboard (it was possible to view up to ten minutes of content on the display), and was visible from across the room. In numerous instances, crew made passing glances at StoryCrate in order to ascertain the current group of shots that were being worked on, enabling them to place themselves in better positions to respond to spontaneous tasks. Conversely, unable to leave his equipment, the Camera Operator monitored matching footage on StoryCrate from across the room; using the Runner to find and playback content (see 27). In both cases, StoryCrate facilitated peripheral awareness of both the current state of the production, and the overall tasks that other crew members were performing. Although my analysis did not concentrate on form factor (as commercially available display technology is rapidly improving) it is worth noting that the large size of the display provided visual access from all areas of the set. When used as a status review tool during planning and review stages (see 35), crew members not directly involved in conversation with the Director could ascertain overall progress of the shoot from the number of storyboard items left without footage.

### *4.6.2 StoryCrate Driving Creative Practice*

Retrospective quality control meta-data was entered into StoryCrate by the Runner rather than replicating the Script Supervisor's notes (see 8). He used the 'take switcher' facility to manipulate re-takes of the same shot, but to compare these takes efficiently, the storyboard was re-purposed, sequencing takes side by side for inline playback (see 13).

**Planning:** The Director used StoryCrate to draw extra storyboard images when planning new actions and alternative plans, which were then dropped into the timeline (see 8), and inserted into place by the Runner. In two instances StoryCrate was appropriated as a planning tool (see 7, 25), primarily making use of the playback functions on StoryCrate. The Script Supervisor summarizes this:

> *"It made us gather, discuss what we were going to do, review the Director's vision and discuss and look at the pictures and what we were physically going to do, rather than just a vague idea." - Script Supervisor*

The ability of StoryCrate to enable the Director to realise his creative vision can be contrasted with the experience without StoryCrate (see 18), which led to uncertainty and an unclear strategy of what the crew was shooting, forcing them to plan only for the next couple of shots, rather than four or five shots ahead (see 10), a situation described as, *"blindly sort of feeling about,"* by the Runner. From observation, fewer changes were made from the plan during the shoots with StoryCrate (6, 24), but this discussion and re-working of the scene had taken place at the start of the shoot, described by the Director as, *"actually more set out from the top, and that's what we* *stuck to. So it's more regimented.",* and later: *"It helped to know where we wanted to be so that we could be flexible to get there".*

**Flexibility and Creativity:** Perhaps as a result of uncertainty as to what 'creativity' as a concept meant to the crew in this context, flexible or spontaneous scenarios were seen as indicators of the production of creative content, such as when the Director makes major changes (see 18). StoryCrate's playback and reference capabilities facilitated this spontaneous workflow despite having an incorrect storyboard: *"It was quite handy to be able to just slot a newly hand drawn shot in between two existing shots in the timeline" – Camera Operator* (see 28), and the Director agrees, *"We were inventing a new scene so I'd say fairly creative but in terms of filming it was basic stuff we were doing"*. According to the crew, their creativity increased throughout the shoot as they became more cohesive as a unit, with a building confidence in StoryCrate. By comparing the Runner's input across the shoot (see 10, 34), we see a responsible and useful creative input emerging. He suggests that knowing the existence of functionality (such as instant playback) in StoryCrate is enough to drive his own creativity, as without StoryCrate (see 23), all possible iterations of a particular scene were shot, because there was no method of checking which one would be appropriate in the final edit.

### *4.6.3 StoryCrate Democratization and Crew Roles*

**Changing Roles:** Recognizing the need for constant maintenance, the StoryCrate operator role was established (see 6), the Director selecting the Runner for this position, the least skilled member of the team. StoryCrate facilitated a major shift in the Director and Runner roles over the duration of the shoot, which normally do not change. Consequently, the Runner traversed through three key stages of interaction with StoryCrate over the duration of the shoot:

***Gatekeeper:*** The Runner was perceived by the rest of the crew as a human proxy for accessing StoryCrate (similar to the camera-operator relationship), performing StoryCrate operations on behalf of other crew members (see 11), especially when the crew leant over him to engage with the interface. All content decisions passed through the Script Supervisor to him before entering StoryCrate. When not available to operate

StoryCrate, content was not maintained, as the crew were not at this point confident in operating it themselves (see 17).

***Teacher:*** By Day 3 the Director had time to use StoryCrate, making a concerted effort to try out editing (see 33), using the Runner to explain complicated tasks (see 31) rather than as a proxy, and sat in the operator chair himself. As little maintenance was performed (see 28), the Director and Script Supervisor used StoryCrate for reference and playback only, giving the Runner alternative tasks instead of keeping him for StoryCrate operation.

***Support:*** Losing the crew's reliance on him to operate StoryCrate as the shoot progressed, the Runner asserted himself as a support technician, retaining content ownership and remaining part of discussions held in the proximity of StoryCrate. Returning from errands to a confused and frustrated Director enabled him to stay with StoryCrate, maintaining data whilst StoryCrate was being used (see 31), making use of un-used areas of the display. Repurposing simple tools to overcome complex workflows, the crew devised custom StoryCrate practices (see 13). The Runner became a base of knowledge for these, so when absent, this knowledge was unavailable to other crew members.

**Democratization:** StoryCrate was designed to fit within a hierarchy of a creative team, whilst driving creativity for all crew members. The Director appreciated that this affected his workflow and included more crew members in discussions (see 7):

> *"I was open to other people's opinions a bit more because they could see where we were. It made my decisions a bit more democratic"- Director*

The crew confirmed this and acknowledged that StoryCrate provided an atmosphere in which they felt able to provide input:

> *"It made us discuss…the Director's vision…look at the pictures and what we were physically going to do, rather than just a vague idea."- Script Supervisor*

Using StoryCrate, the Director was able to build a respectful relationship with the crew regarding creative input by maintaining physical control over the device (see 28), combating his worries about engendering insubordination due to giving the crew too much information, by controlling the information source:

*"There is a danger…of it making too open a process….that could become a dangerous thing towards the work you are doing." - Director*

These fears of insubordination were foremost in the Directors mind throughout. In post reflection however, He felt that his concerns were un-justified given that StoryCrate did not take crew away from their roles and a hierarchy still existed.

## 4.7 Discussion

Although the creative practice of the entire crew was influenced to some extent by StoryCrate, the Director and Runner experienced the most radical changes to their roles and/or ability to make creative input. The analysis suggests these changes were due to both a direct effect on their individual workflow, through interaction with StoryCrate, and the response of the rest of the team to StoryCrate in their periphery. To expose further lessons from this data, I have established three areas of interest which warrant an in-depth discussion: *State Representation*, *Workflow Impact* and *Domain Specificity*. These categories are of interest as I reflect on the crew's creative practice in response to StoryCrate.

### *4.7.1 State Representation*

I observed that the storyboard representation of clips was not fully appropriated, that is, its ability to allow sequencing and playback of clips in the order the viewer would see them edited. Although the storyboard was indeed used as a state representation of shots remaining (by monitoring how many clips were still on a hand-drawn storyboard), the crew were more concerned with the time it would take to film the shot, rather than the length of the content once edited. Replacing the storyboard with an augmented version of the Shoot Order could enable side-by-side playback of clips, at the same time retaining a clear representation of uncompleted tasks, whilst removing the unused chronological playback ability. The Director alone used StoryCrate for testing editing decisions, checking that footage worked together, but this was to be expected as he was anticipating producing his own edit after the shoot. He utilized the storyboard with both footage and images to communicate his vision to the crew, combining pictorial, notes and time-based representations of content to explain his ideas more clearly, particularly before shooting began.

When attaching meta-data to footage, the Runner added appropriate data as it became available, but he was initially instructed by the Script Supervisor on what types of data to include. Due to the lack of feedback in the shoot as to the validity and usefulness of this data for later phases of the production process, the immediate advantage to the Runner performing this task was unknown. Instead of relating these decisions to future editing tasks (which he would not be part of) the meta-data tools were used to tag shots for rapid retrieval from the interface when playback was requested.

The crew gravitated towards StoryCrate as a physically central representation of the shoot content, possibly due to it being located centrally within the space, and the Script Supervisor was situated next to it most of the time. The Director would hold impromptu discussions using StoryCrate as a reference tool, often instigated by his own exploration of the content during spare time. Crew proximity to StoryCrate drew unlikely participants into these creative discussions, which led to input into creative discussions from crew members further down the decision-making hierarchy than would traditionally be the case. StoryCrate externalises subtle creative contributions made by members of the team that normally would have been un-noticed. Through externalising these creative actions, StoryCrate supports collaboration and engagement by other members of the crew with these contributions.

In phases of the shoot involving StoryCrate, crew members were aware of the content that was being produced due to StoryCrate's large screens and central location. The Director reported a perceived reduction in the level of personal pressure he was under, knowing that multiple members of the team were viewing content and monitoring clip quality. This sharing of cognitive load (within the team) allowed the Director to plan further ahead during the shoot without concentrating all his effort into monitoring (current) quality. The other crew members also noted this effect, describing their experience of having confidence in their knowledge of the day's plans because the Director had arranged explicit meetings around StoryCrate, but also because they could check on the current status of the plan at any point.

StoryCrate was designed with the expectation of use while standing. This was to prevent users assuming control over the interface through placement (and perceived ownership) of chairs, and to increase the feeling perception of approachability by any member of the team. However, the Runner used a chair placed in front of StoryCrate. Due to an easier operating position and lack of space either side of the unit, occupancy of the chair became a symbol of power over StoryCrate, and thus power over content decisions. The seat was used as a method of asserting power by both the Runner and Director. For example, the Director would assert control over StoryCrate by asking the Runner to leave his chair, physically removing him from in front of StoryCrate without explicitly instructing the Runner that he was now not required.

### *4.7.2 Workflow Impact*

During the shoot the crew perceived flexibility in their roles as a measurement of their individual creativity. Since the crew are used to working in time-limited and high-pressure situations. Points in the shoot in which plans were changed spontaneously were regarded as incidents of a flexible workflow, and thus a high level of personal creativity. In particular, the Director judged his own creativity by the amount of spontaneous idea generation during the shoot, linking his 'lack of creativity' in phases involving StoryCrate to his more relaxed and informed managerial situation due to prior planning. When StoryCrate was used as a planning tool, the crew experienced fewer moments of spontaneous changes during the shoot, as these changes had been discussed during the planning phase. From this perspective, StoryCrate decreased the crew's perceived creativity level, through supporting pre-planning. In well-integrated teams with a history of working together, team members know each other's working practices which can lead to increased spontaneity. In newly formed teams however, such easy communication and mutual understanding has not been built up, and such spontaneity can lead to misunderstandings and confusion amongst the team. StoryCrate supported the Director's spontaneity by supporting him in planning for the editing phase of production by trialling editing decisions. When these decisions were made during a pre-shoot 'planning' phase (also facilitated by StoryCrate), both the Director and crew perceived an inflexibility during filming, and a limiting of the Director's ability to change decisions spontaneously.

The Director communicated his vision and practical intentions more effectively with the use of StoryCrate, re-appropriating it as a planning tool to explain the practical targets and logistical decisions for the upcoming shoot to the rest of the crew. Using the Anoto pen input, he replaced out-of-date storyboards with his own interpretation, to keep a record of these decisions. By arranging planning sessions based around StoryCrate prior to the shoot commencing, he could concentrate on the task of directing the current shot rather than explicitly communicating all decisions to crew members for tasks later in the shoot.

Although not directly influencing StoryCrate's design, the concept of Flow [22] can be used to describe the benefit of StoryCrate in giving crew an opportunity to engage with the content. Although the Director fears insubordination, StoryCrate enriches their personal interpretation and understanding of the content, even without being directly responsible for content decisions. Although the concept of Flow describes the benefit of providing a fluid and accessible experience to enrich the crew's perceived fulfilment and therefore creativity, some of the crew's reaction to StoryCrate is that of mistrust and a pushback from the new technology and the freedom it gives them, citing that their technical role in the crew comes first.

StoryCrate provided a democratic forum for crew to interact with content without circumventing the decision hierarchy of a TV shoot, however the primary user (the Runner), a crew member with unrivalled access to the content, had much more input into the creative process than traditionally. It was our expectation that facilitating elements of the democratic process would open discussion around the content and enable further creative thinking. By becoming the operator, all interactions with StoryCrate were effectively filtered, either by him performing the action or influencing those who were. This gives a relatively inexperienced and unskilled creative practitioner more input into the content that would have previously been allowed.

Although hired as a relatively unskilled worker, the Runner is involved in most of the creative discussions, in contrast with the Lighting Engineer (who was hired specifically for their skill and experience). This suggests that because the crew was less reliant on the Runner's specific skills, he was more able to integrate StoryCrate into his workflow. For those crew members who rely on complex technology to perform their role, such as Camera and Sound, StoryCrate was perceived as another piece of equipment for others to use. For these crew members, working with technology is a large part of their roles, and StoryCrate was seen as an unnecessary additional tool which they did not need to master in order to complete their job. For those crew without dedicated technology however, StoryCrate's accessible interface facilitated contribution to the content that would not have been possible otherwise.

### *4.7.3 Domain Specificity*

A number of domain specific factors make new technology difficult to deploy in production environments. The crew's own method of measuring success during the shoot is by analysing the time constraints and the time remaining to shoot each shot. Thus when a new technology or process is introduced, it is judged in a cost benefit analysis between output and deployment time. Additionally, task demarcation among professions (who claim particular technology and skills as their own) is important. Introducing a technology that does not fit within these trade boundaries may affect the accountability of the team as to who retains ownership over new devices.

StoryCrate required on-going maintenance during filming and often was not available for editing by the crew due to lack of up-to-date content. Realizing a maintenance role would be a key factor in gaining benefit from StoryCrate, and the Runner was assigned to perform this maintenance whenever possible. Like most production roles, StoryCrate became associated with its operator, who acted as a proxy to its features. Although this allowed the Runner to build up competence in operating it, the crew adversely interpreted this as discouragement for using it themselves, in fear of encroaching on another crew member's specialty. When combining this with the crew's view of creative practice it is difficult to see how having a designated operator for StoryCrate could have facilitated spontaneous interaction by other crew members when the operator was seen as a gatekeeper.

## 4.8 Design Considerations

StoryCrate provides a collection of tools to facilitate creative practice for television production professionals on location. Although not all features were appropriated in line with my expectations, the in-the-wild study indicates that StoryCrate positively affected the creative workflow of the crew, and has demonstrated specific features that benefit these types of situated workflows.

Retrospectively, the shoot exhibited nuanced elements of crew dynamics which influenced StoryCrate's impact on the production process. Production crew are considered skilled specialists in their demarcated roles, often relying on their experience with specific complex equipment, and as such, technology placed in these environments must be sensitive to the clear role boundaries already adhered to by crew members.

Similarly, when designing to facilitate creative practice, it is important to consider who within the workflow will truly benefit from additional access to the creative process, as not all members of the team may actually require direct intervention as a driver of creative practice. Many crew members had existing structured and fulfilling methods of inputting creatively, and may feel intimidated or apathetic towards the suggestion that they might improve their creativity using a shared technology, especially since it is relatively unsophisticated compared to the technology they currently use.

As was demonstrated by the Runner's experience, not having a clear technology responsibility or specific workflow enabled him to re-envision his role, producing useful and creative input that would have otherwise been lost. By contrast, the Lighting Operator did not feel that his creative input would have been improved by new technology as he already had a relationship of mutual trust and communication with the Director, although StoryCrate indirectly allowed him to monitor and improve his own workflow using functions which he did not have access to previously. In the context of a hierarchical creative team structure, it may be a mistake to design for overly democratised collaborative interaction. Instead, locating specific affordances of the shoot which enable members of the crew to either: use down time (like the Runner), or facilitate others to be creative (like the Director) may be enough to drive the team collectively to be more creative.

The tangible controls of StoryCrate supported the discussion and observation of intent within groups of users (such as the Runner and Director), through possession of specific controls, but as the majority of use was by a single gatekeeper operator this did not impact the workflow significantly over touch interaction. However, the ability to place controls on the surface of the display near to where they are often used, but without interacting (placed on their side) was used to overcome continued reaching across the large table surface when controls were needed in similar locations. Limiting the number of physical controls (and therefore function groups of functions in the interface) reduced the perceived amount of learning for the crew, and a number of the crew were content with using only the play and preview controls throughout the shoot. For more advanced users such as the Runner, these controls could be shared with passing users as a token representing temporary release of control over the interface, whilst retaining some power (by holding the rest of the controls himself). Given these positive outcomes for the use of tangible controls, the reliability of the optical tracking system caused some problems with the fluid usability of the controls particularly for intricate operations such as list selection and scrolling. Combining these controls with touch interaction for intuitive operations such as scrolling or scrubbing the timeline would alleviate the reliance on fine grained tangible tracking without introducing complex multi-touch gestures to learn.

StoryCrate needed constant maintenance of data to be beneficial in sporadic scenarios of use involving crew members. The fast moving and unpredictable nature of a film crew means opportunities to interact with new technology are often spontaneous and short lived. As StoryCrate relies on data from other parts of the workflow, it needs to be up-to-date with current video content so that the crew can use it effectively at a moment's notice. Although by promoting peripheral awareness which enabled the crew to be aware of the Director's vision, it may have been insensitive to the Director's requirement for maintaining control over his creative vision. Technology needs to be sensitive to the subtleties of the power structures that exist within the environment of creative production, possibly offering the ability to make certain decisions with the wider crew's oversight. By creating an expectation of mutual awareness, technology could create divisions amongst crew who pride themselves on their personal creative decision making and skill as practitioners. One solution may be to provide a decentralized system of interaction with shoot content, allowing easy re-appropriation and personalization by crew members, who might integrate this technology as part of their personal workflow. Although distribution of technology would facilitate personal interaction, no crew member would be responsible for maintaining a centralized representation, a problem overcome in this study by allocation of a designated operator for StoryCrate.

## 4.9 Conclusion

This chapter presented an in-depth description of an in-the-wild deployment of StoryCrate, a collaborative production tool designed to support creative practice in professional TV production teams during the shoot phase of production. I presented a narrative account of an in-the-wild deployment, using this to guide a reading of the data extracted during the deployment. Through a three stage analysis on this data I highlight key themes which I discuss in detail, resulting in a set of design recommendations. These recommendations pertain to tools that are deployed in situated production teams, and that drive creative practice with professional crew members. A critical reflection on specific instances of StoryCrate's use yielded a number of additional design concerns such as the need for constant maintenance and the potential impact of shared interaction spaces on crew's perception of their own creative practice. Since the deployment of StoryCrate in a real-world scenario, current industry products have demonstrated a move towards meta-data based production with on-location workflows and tools. Products such as BlackMagic's[27] range of cameras with built in meta-data entry capabilities and tools such as Adobe OnLocation[28] allow for real-time (or close to real-time) addition of meta-data and editing decisions. With these advances, on-location systems such as StoryCrate which allow crew to perform simple editing tasks at the point of capture are becoming a realistic possibility.

[27] http://www.blackmagicdesign.com/uk/products/blackmagiccinemacamera

[28] http://www.adobe.com/uk/products/onlocation.html

# Chapter 5. Community Event Production

*WITH PRODUCTIONCRATE*

## 5.1 Introduction

Academic conferences are difficult, expensive and time consuming to organize. Many research communities do not have the collective resources to maintain a central organization that arranges regular events and often it is the role of volunteers to source venues, staff and equipment to run them. Increasingly, such events integrate multimedia streams of content in order to drive conversations and topic discussion between attendees, creating further technical and organizational complexity. Such 'Community of Interest' (COI) events often present social media feeds, supplementary video and audio content and digital content as part of the attendee experience, displaying this content in a variety of forms including ambient displays, interactive programmes and mobile applications. This evolving level of integration with dynamic media and content is necessitating a scaling in both consumer technology at the event and the processes needed to produce and manage such experiences. Attendees can consume social content such as Twitter and Facebook with live streaming video and supplementary image content related to the event. Such integration adds complexity to the logistical and technical organisation of the event by introducing new roles, technology and management tasks.

While the largest of academic conferences have professional event management services, smaller events that consist of between 200 and 300 attendees rely on volunteers. This typically means making use of members of each host institution as event staff, transferring control from one event to the next. Inevitably, most COIs do not have a central organisation that manages on-going financial or technical resources for each event. When new media content and routes for participation with the event are introduced, the responsibility for deploying, producing and managing this additional digital content also falls to members of the COI.

ProductionCrate was designed as an integrated digital production system that facilitates the workflows associated with managing digital content by members of a COI during a situated event. ProductionCrate provides tools and an infrastructure for producing, maintaining, routing and directing a wide range of media content during such an event and, uniquely, is targeted at members of the COI community who are participating in the event as attendees. ProductionCrate supports these attendees in performing complex production roles even though they do not have previous production experience. ProductionCrate allows video, social media, images and static event content to be integrated into the attendee media consumption experience to stimulate discussion and engage participants with event content. ProductionCrate integrates multiple input, output and infrastructure technologies, enabling attendees to facilitate their own discussions via social media whilst also consuming content produced during the event.

ProductionCrate was developed in response to the real-world requirement of a system to be deployed at two international academic conferences that my research group was to host in 2012. These events provided an opportunity to enhance the attendee experience through social and video media to drive engagement with event content. I had to accomplish this without hiring additional professional event technology or staff. Unlike StoryCrate, which was developed to support professional production teams, ProductionCrate facilitates members of the COI community, who I call 'hybrid-attendees', to perform production tasks during a COI event. ProductionCrate was developed to fulfil two key roles for these events:

i) ProductionCrate makes use of volunteer COI members to manage a rich multi-media experience for all attendees.

ii) ProductionCrate simultaneously encourages attendees to engage with digital event content to drive their own conversations and give them a richer live experience.

Over the next three chapters I describe the situational factors that impact on COI events, explicitly citing the academic conference scenario for which ProductionCrate was specifically designed and deployed. I describe the infrastructure developed to support 'hybrid-attendee' production teams and lay the foundation of design and implementation required for both the attendee and production experiences that I was aiming to facilitate. In this chapter I discuss the COI production scenario in detail, drawing on literature and past work to support the notion of attendee media engagement. In particular this chapter centres on the design requirements that emerge for such a collaborative system. In Chapter 6 I present the design of the specific production tools within ProductionCrate that support the hybrid-attendee production workflow and how they respond to the challenges identified in Chapter 5. Concluding with Chapter 7, I record the initial deployment at the two academic conferences organised by my group, and then describe a follow-up deployment I arranged to validate the results gained from these. An analysis of the in-the-wild deployment and a discussion around the effect of ProductionCrate in supporting 'hybrid-attendee' production in COI events concludes this case study.

## 5.2 Media Production

Observations of professional live production teams are rare and domain specific, even within live production. Engström and his collaborators, have examined the work of broadcast production teams, in a range of studies and interventions including ice hockey match TV production. Starting first with an observational ethnography of a live production team (Engstrom et al., 2008), the work primarily focused on learning about the complex inter-team relationships and practices which enable professional TV production; it had the aim of establishing requirements for the development of tools for amateur production teams. Following this initial work, Perry *et al.* responded with a set of design implications for developing technology for this unique group of users (Perry, Juhlin, Esbjörnsson, & Engström, 2009). These implications are in many ways consistent with those considered for the design of StoryCrate, but this study highlights three key implications when designing for broadcast production workflows, particularly targeted at non-professionals rather than professional teams:

1. *Recurrent activities and recognisable patterns*: Especially within sport broadcasting, the content that is being filmed and broadcast consists of regular and repeated actions. The production workflow can be streamlined and the need for explicit communication lessened if the team understands a common set of these repetitive activities that requires clear reaction on the part of each team member. An example could be where each member of the team automatically responds to a goal score with a change in their task without explicit command from the director.

2. *Task negotiation and job allocation*: Unlike some other complex cooperative domains, resources in a live production (both human and technological) are in high demand at all times. In order to produce a useable narrative of video from multiple

cameras, these cameras must be capturing footage that is both useful and timely for the editor. From past experience performing their roles at similar events and by working with each other, the team learns to prepare itself for shots that are useful for the editor without explicit command. With inexperienced teams however, shot preparation will need to be facilitated and controlled more directly.

3. *Camera-mediated coordination mechanisms*: Most professional teams operate with a primarily one-directional communication link from the vision mixer (live editor) to the camera operator, which in professional environments works because the camera operator is quick enough to align shots without much description or coaching. In an amateur environment, extra non-verbal communication channels could be used such as tally lights, or 'I'm ready to shoot' indicators from the camera operators to the vision mixer to help communicate the state of the operators.

In relation to another study of ice hockey game production, Nou et al. discuss the benefits of creating an easy to use production environment which provides the opportunity for creative practice by the crew during a live event (Nou & Sjolinder, 2011). While studying the effects of broadcast quality for viewers' own virtual presence at the event, the study also highlights that by presenting crew members (both professional and amateur alike) with 'professional' looking equipment, their own self expectations were raised, driving them to produce better quality content (or at least have that expectation).

Even within the research conducted around professional production teams, the primary direction of interest is the facilitation of relative amateurs to produce better quality, better produced, more accessible content. This emphasis is possibly linked to the availability and ubiquitous nature of video capable technology such as smartphones, video cameras, editing software and distribution platforms such as YouTube[29] and Livestream[30].

Engström proposed the idea of collaborative distributed video editing in 2007 (A Engström & Esbjörnsson, 2007), discussing the requirements of such a system,

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[29] http://www.youtube.com/

[30] http://www.livestream.com/

including: live editing, team communication, division of labour, on-going workflow negotiation and event overviews. This was followed by an example implementation and study of ‘SwarmCam’, a mobile infrastructure for capturing a live event, producing content which can be then used by the VJ (Visual disc Jockey) to produce more content live (A. Engström, Esbjörnsson, & Juhlin, 2008). In this study the audience participate as both consumers and producers of visual content, re-capturing their own unique experience of the event with the intention that others should view it, creating a feedback loop between themselves as the audience, themselves as producers of content, and the VJ feeding the content back into the venue. Audience members use skills in video capture, mobile editing and device manipulation which are now relatively common in members of the general public. Advances in consumer mobile technology (such as smart phones) allow this to be carried out instantly. The CoMedia mobile application is a similar community production tool enabling participants at live events such as motor rallies to create a social media community with both other co-located participants and those remotely connecting via the web. Running as a mobile application, this tool enables participants at the events to capture and disseminate video and image media taken throughout the event, publishing it for others to consume (Giulio Jacucci, Oulasvirta, & Ilmonen, 2007).

Interestingly, with the development and availability of tangible user interface technology, video editing has presented a domain in which these interfaces can be deployed with significant benefits over existing interfaces. ‘Logjam’ (Cohen, Withgott, & Piernot, 1999) and the ‘TVE’ (Tangible Video Editor) (Zigelbaum et al., 2007) were both presented as tangible video editors to enable collaborative production of video narratives using tangible tools to represent transitions, effects and media. Both these systems are designed for offline editing of static media, whereas ‘MediaCrate’ was a tangible tabletop system which replaced the traditional linear live video production workflow with a collaborative table top interface. By abstracting the functions from a number of different hardware devices such as a vision mixer, media player and lyrics engine, ‘MediaCrate’ allowed the team to dynamically reorganise roles depending on the tasks and skills required (Bartindale et al., 2009a). Although not targeted at video editing, the Anecdote system provides a storyboard-based representation of application interaction, in which ‘surrogate’ representations of complex screens are arranged to describe navigation through an application (Harada et al., 1996). Driving Anecdote provides a seamless transition from a 'surrogate' representation (still images) to a fully working application. This is analogous to film storyboarding where static storyboard tiles would be replaced by real footage.

## 5.3 Academic Conferences as Situated Events

Fischer has described how 'communities of interest' form around a particular topic of shared involvement regardless of other social factors (Fischer, 2001). A common method of supporting these groups is to gather people together in a located event purely to engage with the shared topic. Academic conferences are a long-standing example of this type of COI activity, in which students, academics and industry researchers from across the world come together to present and discuss specific areas of research. These events are environments in which attendees absorb information, build relationships within the community and are inspired and energised. Consequently, technologies allowing us improved communication with fellow attendees and better access to conference materials are becoming increasingly common, particularly as these technologies become more mobile. As a group who are often early adopters of technology, this has been particularly visible in the HCI community, and it is this openness to engagement that has motivated me to better understand the impact of technology on the conference experience and allows me to explore what form the next generation of conference technologies might take.

In recent years there has been considerable interest in the role of social media supporting face-to-face (McCarthy, Boyd, et al., 2004) and 'backchannel' (Harry, Green, & Donath, 2009) discussion at live events. It is also now common for these events to film, stream and archive content (e.g. ACM TEI and PDC in 2012), and many events provide smartphone apps to help attendees navigate content (e.g. Edinburgh Fringe Festival[31]). These services are often stand-alone, un-moderated, and lack integration with the primary media production system, resulting in media streams of multiple formats which are consumed across multiple different devices but which lack a coherent narrative which bind them into a directed production.

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[31] https://www.edfringe.com/

The smaller (200-300 person) conference events ProductionCrate was targeted at typically make use of community members associated with a local interest group hosting and staffing the event. I refer to these volunteers as '**hybrid-attendees**', who are acting both as staff members and as members of the COI to perform production roles during the event. This situation raises a number of issues. First, the technical capability to run this type of event depends on deploying custom technology or funding external contractors to deliver self-contained services (e.g. to stream video). Second, most volunteers from the community will not be skilled in the specific tasks needed to support live event production technologies.

My research group hosted two international computing conferences over the summer of 2012 which I used as case studies for the design and deployment of ProductionCrate. Over the two-week period, a total of 800 attendees from across the world attended 46 sessions, 33 workshops, 2 dinners, 2 demo sessions and 130 presentations in 3 simultaneous venues. The diverse attendee participation and content engagement opportunities during this time offer a classic scenario of an academic event. In the first week, our group ran the ACM Conference on Designing Interactive Systems (DIS)[32], an event primarily dedicated to the concerns of members within ACM SIGCHI with an interest in design issues. The following week our group hosted the Tenth International Conference on Pervasive Computing (Pervasive[33]), a more technology-focused conference dedicated to ubiquitous and pervasive computing, which was co-located with the IEEE International Symposium on Wearable Computing (ISWC)[34]. Each conference had organisation and program committees primarily responsible for content and the review process, whereas event logistics and production was centrally managed by myself and a team from with my research group.

Opportunities to deploy new technology to enhance the attendee experience on this scale are difficult to organise. In this case, budget constraints (typical of COI events) prohibited the purchase of commercial production systems for attendee experience enhancement (such as professional video capture), especially as the hybrid-attendees

[32] http://dis2012.org

[33] http://pervasiveconference.org/2012/

[34] http://www.iswc.net/iswc12/

would not be skilled in the operation of professional grade technology. To overcome these constraints, I chose to design, develop and deploy a multi-faceted content infrastructure to enhance the attendee experience without passing the expense onto attendees as would be the case when sub-contracting to multiple external organisations.

Organising a shared infrastructure for these conferences provided me with an opportunity to explore how to integrate novel attendee facing technologies into the conference experience. Although individual items of technology have been trialled at COI events in the past, I attempted to envision how technologies might be used throughout multiple aspects of the conference and how this impacts upon the delegate experience. ProductionCrate was developed to facilitate the collective editing, redistribution and management of event media to support these types of attendee facing media outlets.

I was acutely aware that deploying such a large set of interrelated systems simultaneously would be challenging. This was compounded by only having limited access to the event venue prior to its opening day, allowing only 12 hours of set-up time. Furthermore, alongside this deployment the event production team would additionally have to comply with situated requirements related to running events of this size, such as directing attendees and volunteers to correct venues and locations, ensuring adequate provision of catering and refreshments during the event, and managing presenter technical equipment and sound re-enforcement. Attendees would pay £390 or more (£230 or more for students) to attend each conference which, gives rise to certain expectations on the quality of the 'product' despite the general awareness that only "amateur" members of the community were organising the event.

## 5.4 Increased Production Value

StoryCrate was designed to drive creativity within an established and highly skilled production team through supporting and scaffolding the team's own creative practice. However, as a production workflow tool for hybrid-attendees that aims to support dynamic response to factors elsewhere in the event, my design goal with ProductionCrate was to support increased production values for an integrated attendee media experience. ProductionCrate was designed to support hybrid-attendees in delivering an event with clear production value for attendees, supporting them in engaging with event content. To ***drive attendee engagement with content*** and ***increase media production values***, we must ***support hybrid-attendees*** in their fulfilment of situated production roles.

### *5.4.1 Driving Attendee Engagement*

One of the main values of academic conferences over other dissemination channels is the ability for attendees to meet new people and enter into discussions. We wanted to fully embrace the growing trend—exemplified in the use of mobile apps, social media and public displays—of making content from the conference available and searchable through multiple channels, thus linking the situated 'meeting' to the 'media' that is associated with it as an event. To bootstrap production content and scaffold social discussion we made both the content submitted to the conference (papers, videos and photos) and the content generated during the conference (tweets, photos and interviews) widely available during the event. A key element in the planning of these conference events would be that attendees become part of the production process as producers as well as consumers, driving attendees to contribute content via digital media channels such as social media, video and image content. By creating content, attendees would relish their stake in the shared content stream and in return become more engaged in the discussions that emerge.

There is precedent for deploying technology in academic conference venues, and significant adoption of mainstream technologies to mediate conference experiences. COI events have rich potential for augmentation by new technologies, and conferences in HCI have long been seen as a valuable deployment site for new technologies that engage attendees in social experiences. I have summarised these past explorations and deployments into three categories of attendee event engagement: *connections & networking*, *content visibility*, and *new channels of communication*.

**Connecting and Networking:** For many people, conferences are both a time to reunite with old friends and colleagues and a time to network and build new relationships. However, these opportunities are "unevenly distributed among the attendees" (McCarthy, McDonald, Soroczak, Nguyen, & Rashid, 2004), favouring more experienced or extroverted attendees over newer members of the community who might benefit more from networking. As a result, many

conference technologies have sought to identify attendees, suggest potential beneficial contacts and offer icebreakers and other prompts to encourage socialisation. Often, these have built upon the familiar concept of a conference badge, which is a common means of identifying others and a convenient placement for sensors, emitters or small displays. Examples of identifying tags include UbiCoAssist (Hope et al., 2006), which used sensors to identify users exploring a social network graph and IntelliBadge, which tracked users and allowed them to locate other attendees (Cox, Kindratenko, & Pointer, 2003). By comparison Meme Tags (Borovoy et al., 1998) was a more playful system designed as an icebreaker, which allowed wearers to display and swap short messages.
Possibly the best known examples, combining a number of different technologies, are AutoSpeakerID and Ticket2Talk, deployed around UbiComp 2003 (McCarthy, McDonald, et al., 2004). These systems both utilised personal tags that identified speakers asking questions and offered conversation topics to attendees standing near dynamic displays. This study is noteworthy for examining not just the use of a particular technology, but also the impact a collection of technologies had on the overall attendee conference experience. McCarthy *et al*. concluded that they were perhaps overly cautious in attempting to maintain privacy and integrate the technologies into existing conference practices. Few attendees had major privacy concerns, while it was found that “meshing with existing practices may not be a reasonable goal” when deploying technologies into venues.

**Making Content Visible**: In addition to a traditional paper programme, many conferences now provide a mobile app, typically including the full programme and the ability to create a personalised schedule and reading list. Recommender systems designed to help attendees navigate a large number of sessions have also been suggested for mobile devices, such as the Conference Assistant (Dey & Salber, 1999). Public displays have been one of the most common forms of conference technology and it is now common to see large non-interactive displays of scheduling information, particularly at larger conferences held in dedicated conference venues. Attempts at creating conference displays extend back at least to CHI 1989, where the InfoBooth (Salomon, 1990) kiosk provided access to information about the conference content, people attending the conference and the host city. The evaluation of InfoBooth focused largely on usability testing of the kiosks, aiming to provide an interface that could be quickly learned and used by attendees who had not seen it before. Whereas InfoBooth concentrated on pre-defined data, PhotoFinder Kiosk at CHI 2001 provided access to user-generated content in the form of photographs created and uploaded during the conference (Kules, Kang, & Plaisant, 2004). The e-Campus project also explored the use of a large network of displays during a workshop, including navigation tools (Storz, Friday, & Davies, 2006).

**New Channels of Communication:** As networked technologies have become pervasive, connections between attendees have extended beyond face-to-face socialisation. Multiple technologies have been used to create digital 'backchannels' at conference events—a secondary communication channel that occurs at the same time as presentations and face-to-face interaction. In these channels attendees at many conferences have expressed opinions and discussed with other participants in both serious and light-hearted fashions, sometimes anonymously and occasionally mischievously (Kirman, Lineham, & Lawson, 2012). Even before social networks like Twitter became mainstays of the conference experience, the ACM Conference on Computer Supported Cooperative Work in 2004 created official IRC channels for each venue track (McCarthy, Boyd, et al., 2004). These were used for a variety of purposes, including discussion of the main presentation, but also extending to logistics such as ascertaining someone's location. Concerns were raised, however, about the effect of backchannels on the amount of attention paid to the presentations themselves. Other conferences have made use of web-based communities to encourage interaction before, during and after the conference, including CHIplace and CSCWplace (Churchill, Girgensohn, Nelson, & Lee, 2004) and the recent Buzzy portal at CSCW 2012. These systems also used displays to serve as a means of connecting the conference's online presence with the event itself, blurring the distinction between online and offline interaction.

While there is certainly potential for backchannels to act as one more source of distraction during presentations, it is also possible for them to offer a *productive* distraction that stays on-topic and involves other members of the audience (Golub, 2005), including co-authors, who do not typically play a role during the presentation (Rekimoto, Ayatsuka, Uoi, & Arai, 1998). Backchannels have often been used as part of the questions segment of presentations, either by supporting clarification on small points so that questions can focus on more critical topics, or by submitting questions in advance so that the session chair is better able to curate the discussion and select interesting topics. For example, backchan.nl (Harry et al., 2009) allowed conference delegates to post questions for panels through a web interface and vote questions ‘up’ or ‘down’, with the top questions being displayed for the audience to see.

### *5.4.2 Increasing Production Values*

In traditional media production contexts such as live concerts or sporting events, there exists an expectation and understanding of the media production values that should be maintained. For multi-format experiences using new technologies in events which have previously not used such media production tools, however, there is no tacit understanding by attendees of what a ‘good’ production is, and what values to apply to the event to judge value. One aspect of the relationship between attendees and an event can be characterized through the notion of ‘liveness’ (Auslander, 2008). By referring to the liveness of an event, it is suggested that there is an intimacy between attendees and immersion in the event itself that is often difficult to provide in non-collocated contexts. While contemporary notions of liveness draw primarily from the performance arts (Varney & Fensham, 2000), I see the benefits of engaging conference attendees directly with content in a variety of ways.

Live television broadcasts are a common example of supporting the attendee experience through bringing in streams from multiple locations to tell a singular story (Verna, 1987) whilst maintaining a sense of liveness for spectators. Using this analogy, I can describe the processes needed to generate multi-format, trans-media, evolving content within the context of co-located media consumption at live events, whilst using user-generated content as available production media, similar to the curated content that becomes available to museums in participatory exhibits (Barry, 2010).

Drawing from the structure of live television broadcast production, ProductionCrate integrates multiple input, output, and infrastructure technologies into a suite of event production tools. Likewise I can start to frame these events as a form of live directed media production, similar to that of a live sports event or music concert. In this way, I can target the development of the attendee experience towards the kinds of media production values that are associated with these events. Live television production teams work towards producing a single television output through which they tell a narrative, but one of the challenges at an academic conference event is to deliver a cohesive narrative across multiple different output channels. Newstream (Martin & Holtzman, 2010) maintained a journalistic narrative across multiple devices by centrally curating content and allowed users to invest in content socially demonstrating the plausibility of this technique. Benford *et al.*'s (Benford, Giannachi, Koleva, & Rodden, 2009) notion of trajectories, which describes a set of narrative parameters that are crafted by production teams to create guided event scenarios for both audiences and spectators, is another useful perspective, especially when considering the hybrid-attendees. Similarly, McCarthy *et al.* describe their experience of augmenting academic conferences with new channels of communication (McCarthy, McDonald, et al., 2004), using elements of guided interaction to enhance the attendee experience. Such examples typically incorporate custom technologies and unique interactions to augment the events considered. By leveraging the ubiquity of social media and mobile technologies (Qualman, 2010) among event attendees, I hoped to provide a rich set of tools for attendees to interact without the unnecessary burden of learning (or installing) new technologies, benefiting from the social conventions of use (Java, Song, Finin, & Tseng, 2007) with existing social media tools.

### *5.4.3 Supporting Hybrid-Attendees*

To deliver an integrated directed narrative which promotes liveness in the event, production teams must curate and administer large amounts of both static and dynamically generated content. In professional contexts such as music festivals, these teams consist of highly trained, experienced professionals, each with dedicated roles such as those described in Chapter 1. Conversely, in my scenario, production staff are volunteer members of the COI. Benford's (Benford et al., 2009) model gives us further insight into facilitating a trajectory that allows staff to move seamlessly between consumer and producer of content, blurring the line between the roles of staff member and attendee. Watch-and-comment (Cattelan, Teixeira, Goularte, & Pimentel, 2008) makes advantageous use of this role-switching, with an approach to video editing that uses the viewer's conceptual understanding of the content in order to collaboratively edit video. In this system it is advantageous to use staff engaged as content consumers to improve the quality of their content editing.

Prior research on professional production workflows, discussed in Chapter 1, reinforces widely accepted design requirements for complex team-based workflows, categorizing design concerns into two primary areas:

i) reducing the cognitive load (and training needs) of each specific role, and
ii) providing a shared awareness of the rest of the team, state of the production, and the event as a whole to all members of the team.

**Cognitive Load:** Hybrid-attendees experience the event primarily as attendees, introducing elements of cognitive load that expert staff would not experience when asked to perform production tasks. This load can be characterized by the division of their attention between management tasks and event participation, the switching of roles between attendee and staff, and the operation of unfamiliar technology and workflows (Storz et al., 2006). An approach to reduce load when moving between roles is to reduce all production tasks into small, simplified chunks that can be performed with minimal additional cognitive load (Oviatt, 2006). Additionally, since hybrid-attendees will be distributed across venues, it is vital that each chunk of the production process remains self-contained and provides clear feedback to its operator so that constant communication does not have to be maintained and operators are co-located. This is because most of the time the operator will have no peripheral awareness of the state of other event media streams due to their physical location, i.e. not being near any public displays. These novice workers are by definition operating outside of their area of expertise, so it is important that the production technology is designed for both their current skill level and to support a rapid learning curve towards proficiency of use. As noted by Engström *et al.*, novice workers lack the confidence to transfer their own skills into new task domains (A. Engström et al., 2008), and instead look to each other for support; and although proficient in other complex tasks, they will not have the prior experience necessary to make reflexive judgments in decisive situations without increased cognitive load (Schon & DeSanctis, 1986).

**Shared Representation:** Earlier media production prototypes such as MediaCrate (Tom Bartindale, Hook, & Olivier, 2009b) and StoryCrate (0) provided a centralized state representation of the current production visible to all members of the production team, but necessitate a physical presence with the system. In production environments where the crew are physically distributed across a site, or between multiple sites, providing a centralised interface for the crew is impossible. In contrast, production environments situated within the same room or studio such as TV production make use of multi-modal communication (voice communication, visual feedback and recording indicator lamps) to mediate between the production booth and the physically distant film crew. Broth observed that mediating technology in TV production creates an asymmetric and clearly defined flow of information between the sound stage and the control room, providing a state of mutual attention for the team (Broth, 2004).

In situations without a centralised control room (and therefore without a centralised source of communication), it is necessary to make each team member aware of the state of other members and their tasks, (as this is not implicit by their co-location), as well as the overall status of the production output. Pentland *et al.* proposed that increasing awareness amongst distributed team members can facilitate team cohesiveness across this spatial distance (Pentland, Hinds, & Kim, 2012). Similarly, (Arvid Engström, Perry, & Juhlin, 2012) discussed the need for adequate temporal awareness, especially in collaborative production. To facilitate this awareness, Tang *et al*. suggested that live voice communication is an appropriate method of supporting coordination amongst distributed team members (Tang, Massey, Wong, Reilly, & Edwards, 2012).

## 5.5 Media Production Requirements

Drawing from previous work in driving attendee engagement, a set of attendee-facing technologies (e.g. public displays) were selected by the event production team to deliver the rich situated attendee media experience and support interaction with social networking and engagement with event content. This rich experience would consist of video, audio, text, image and document content which would be broadcast to devices around the venue and accessible at a variety of interactive locations. Through attendees engaging with this content throughout the event, the organisers wished to drive discussion, deeper understanding and awareness of event related content which would have otherwise not been possible. These technologies would be situated throughout the conference venues, providing a variety of ways for attendees to view or interact with content. The technologies and interaction configurations were chosen specifically by the event production team with regards to the precise venues and event logistical considerations, with an expectation that up-to-date, relevant and responsive content would be accessible across these technologies. Whilst this unique set of technologies forms the attendee-facing (and output) part of the ProductionCrate system, the primary aim of ProductionCrate was to support the management and delivery of content to these devices by hybrid-attendees. The media output of ProductionCrate would consist of a set of live and recorded media which is used for attendee engagement, offsite access to content, event posterity and documentary archive. The production tasks associated with maintaining a responsive and socially driven content narrative for these outputs forms the basis of the design requirements for ProductionCrate. Each attendee-facing component was chosen to support particular aspects of the attendee experience and present key challenges for the production processes and supporting media delivery infrastructure needed to maintain them.

### 5.5.1 Interactive Tables

To support both socialisation and visibility of content, six small interactive tables were deployed around the main conference venue (Figure 22).Each table could be used to browse the conference programme, including all papers and videos submitted to the conference and images harvested from the papers. Content generated during the conference—including tweets, photos, videos of talks and interviews with delegates—were also added to the tables. Attendees could search the content using either their badge tag, which would highlight all content that they appeared in, or using a free text search. Users could also 'like' items of content and export these items onto a USB memory stick inserted into the side of the unit. It was intended that these would form gathering places for groups of attendees during breaks, encouraging interaction between attendees and collaborative discovery of video, document and live event content.


*Figure 22 Interactive SmartTable Coffee Stand*

### 5.5.2 Public Displays (TV Channel)

A number of ambient information displays were also deployed around the conference venues, aimed at further increasing the visibility of content being produced during the conference. These were capable of displaying a variety of content curated by the conference staff, including photos, videos, tweets, announcements and data from the talk timers showing talk progress. Displays were located in the main venue foyer outside each of the lecture theatres, and on the walls of the lunch and demo venue.


*Figure 23 HTML5 Display Located in Lunch Venue*

### 5.5.3 *Scrolling LED Displays*

In each lecture theatre, a scrolling LED sign (Figure 24) displayed tweets that had been posted with the conference hash tag, showing the last twenty tweets in rotation. These were designed to encourage a conference backchannel through Twitter and bring content from this channel to the attention of delegates who might not normally become involved. It was also hoped that tweets appearing on the display would spur discussion during question sessions. As with many academic conferences, a Twitter hash tag was provided that allowed users to search for and submit tweets relevant to the conference. In addition, each individual session was also given a unique hash tag: for example, the opening keynote had the hash tag "#keynote1". These were intended to make the backchannel more easily searchable and navigable by allowing users to identify tweets from the session they were in, rather than those relating to parallel sessions or the conference in general. Each Twitter display was mounted in a conference branded panel which included a space for the appropriate session hash tags, which were added in prior to each session by the Session Chair.


*Figure 24 Scrolling LED Display in Situ at the Front of a Presentation Venue*

### 5.5.4 *Mobile Application*

A smartphone app (iOS and Android versions) was made available in advance of the event. The app's functionality was typical of those provided by many other conferences, with a searchable program indexed by author and institution and the ability to build a personalised itinerary for during the conference and a reading list for afterwards. Tweets could also be directly posted from this application, which appended the appropriate hash-tags to the message.

### *5.5.5 External Website Integration*

During the event, the conference webpage provided off-site access to a variety of social media streams and live video. The current and up-coming programme was displayed along with two curated video streams from inside the event. This was accompanied by the Twitter and Flickr feeds updating in real-time. Although all venue video streams and content could be accessed from inside the conference venue (and network), ProductionCrate includes the facility to broadcast a number of external streams to Content Distributor Networks (CDN), for viewing by external consumers. Each output 'channel' can be mixed independently, and include live and pre-recorded video, static content, social media and programme information overlaid with event branding. This stream could then be accessed through a charging gateway, or to the general public through the event website.


*Figure 25 Second Screen Event Page on the Conference Website*

### *5.5.6 .NET Gadgeteer Workshop Engagement*

Microsoft .NET Gadgeteer (Villar et al., 2011) is a hardware prototype platform for rapid development of high level hardware applications. To introduce the research community to Gadgeteer, members of my research group facilitated a workshop at the start of the conference event in which attendees could learn Gadgeteer development while getting a hands-on experience with the hardware. In tune with the open-source nature of the Gadgeteer platform, and in the spirit of openness which drives research communities who participate in academic conferences, we opened up the production technologies deployed throughout the conference event, encouraging workshop participants to design a novel hardware-based system which could be deployed within one of the event venues during the remaining three days of the event, allowing attendees to interface with the media production system. I felt it important that the prototypes were able to affect the real world production of the event as a whole, so a simple API was developed for Gadgeteer which enabled prototypes to interact with ProductionCrate content at a high level. Limited computational resources on the Gadgeteer necessitated a low-dependency, low latency communication interface to ProductionCrate, so an interface was developed using HTTP requests to the ProductionCrate server which returned simplified (easy to parse) JSON formatted content. This content was then presented to the Gadgeteer developer as instances of simple class types for use in their prototypes. As well as retrieving content available in the ProductionCrate data store, Gadgeteer was also able to control various aspects of the production including creating images and tweets, and routing content to displays.


*Figure 26 .NET Gadgeteer Workshop Prototype*

## 5.6 Supporting Technology

To support the production of a multi-format, responsive, multi-modal media experience across multiple venues, ProductionCrate required an integrated content management system to organise media sources, routing, control and distribution. This middleware and networking infrastructure would form the basis for all production and consumer equipment deployed at the event. By offloading complex operations such as video editing and streaming to robust off-the-shelf solutions this infrastructure provided simple abstractions for production tasks.

### *5.6.1 Repository Architecture*

To support aggregation and storage of content from numerous sources and output to multiple types of devices across multiple technology platforms, I deployed a network-based data infrastructure. This allowed equipment to be deployed anywhere in the conference venue where Wi-Fi or Ethernet was available and removed the requirement for us to support a custom data infrastructure. The common networking design style of a central content repository which is accessible from multiple client devices is directly applicable to the storage and manipulation of production media (Figure 27). Media is produced by clients and stored in the repository, and subsequent production tasks are performed by taking the media from the repository onto a particular device, performing an action and then pushing it back into the repository. In ProductionCrate, this repository is implemented as a networked Linux server and file store, which provides access to all of the media content available at an event through simple APIs. The server exposed a number of API options for accessing data in ProductionCrate, depending on both the volume of traffic and processing availability on the target system. Most high volume communication between clients and the server was carried out through a MySQL interface server using a language-specific API such as ODBC, while smaller embedded devices such as .NET Gadgeteer made use of a REST JSON API exposed through the ProductionCrate web server. Low power target devices such as HTML displays could access content through rendering HTML content from the ProductionCrate web server in a browser, using AJAX requests for content updates via the REST API (using AJAX).

All media content is stored either in the MySQL database, as with text-based media such as Twitter messages, or in large hard disk volume on the server. This volume is accessible through a Samba (Windows File Sharing) server and through the media-streaming server as a HTTP video stream. Devices consuming media are expected to initiate content requests to avoid large amounts of data being transmitted without explicit commands. The video streaming server and devices that provide editing services upload edited video content to the file store for centralised access by other clients and production tools.

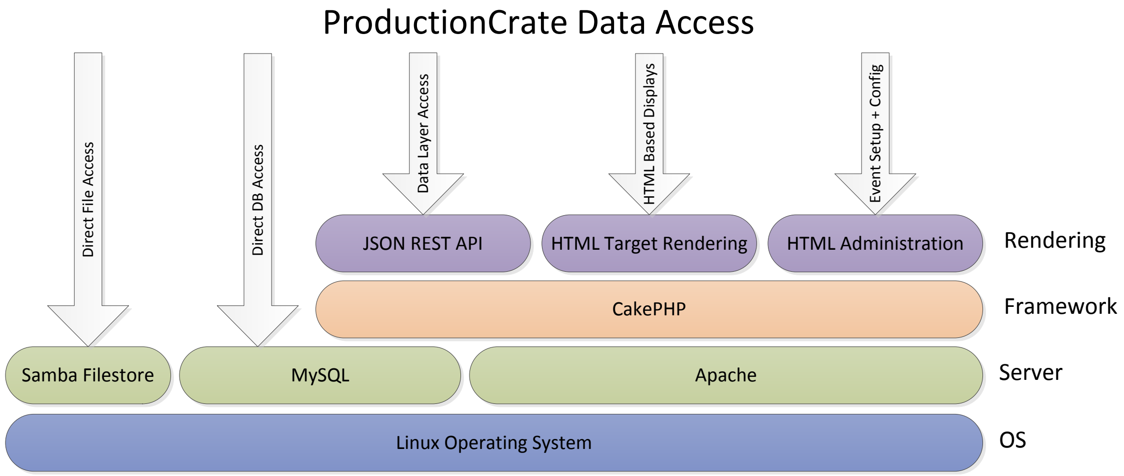


*Figure 27 ProductionCrate Server Architecture*

ProductionCrate was developed incrementally, starting with this content delivery infrastructure. During the initial phases of development, the database consisted of only two tables (*users* and *data*). Although using a single reconfigurable table is inconsistent with common database normalisation practice (Date, 2005), I believed that simplifying the database structure would allow me to incrementally build up the system and be flexible to new media types as they were developed, and thus: simplify backup, restore and record fixing; allow easy addition of new data types during development; simplify target implementation (e.g. on embedded technology); and avoid inconsistencies in schema implementation across devices. The *data* table was structured to facilitate a pseudo-hierarchical data structure within a single table using a field-referenced foreign key within the same table. In this way, many different hierarchical data structures could be stored using a simple table (See Figure 28). On each loosely connected device in the ProductionCrate network, data is cached to allow both network disruption and server failure. Network failure was further suppressed by deploying ProductionCrate on an alternative network to attendees in the event venue.

### *5.6.2 Media Routing*

I refer to playing a selected source media item on a target presentation device as media routing. Most often this involves streaming a video to a public display screen, or displaying Tweets on a scrolling display, although many other types are accepted

(Figure 28). ProductionCrate APIs provide an abstract implementation of media routing, in which source media can consist of any type of media (e.g. video, image, text), and target devices are only identified by the type of media they can render within production controllers such that if a source is to be displayed on a target, this target must implement a method of displaying this type of media. For example, an LED display and a HTML5 webpage can both display a Tweet, but it is up to the specific implementation of the target device (the webpage or the LED driver) to implement exactly how a Tweet will be rendered.

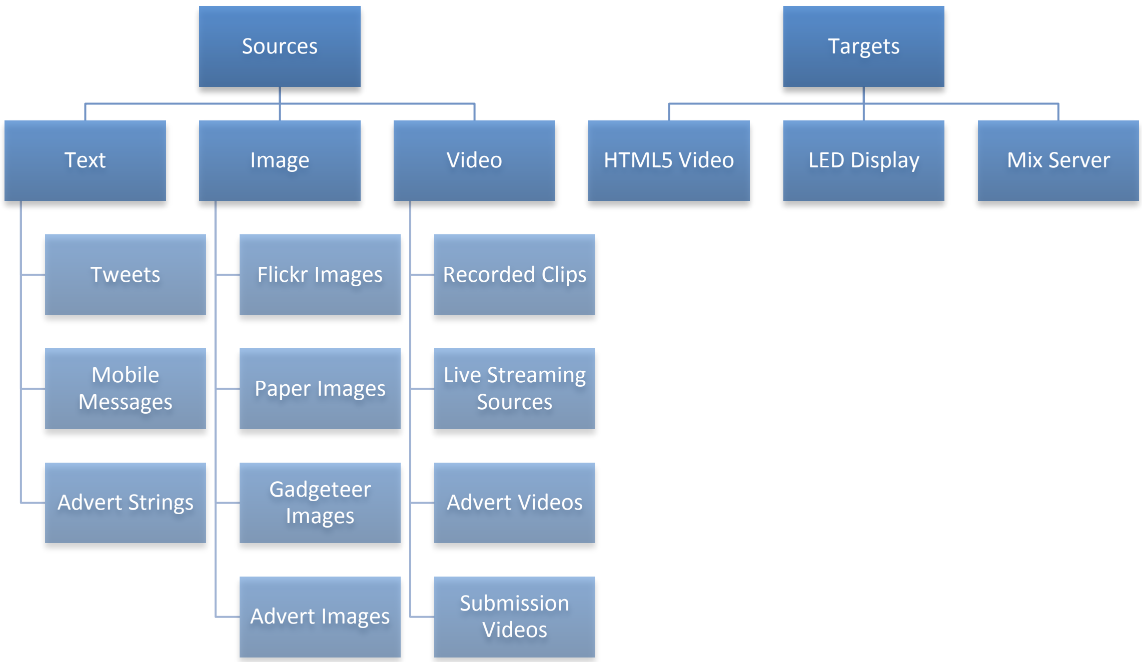


*Figure 28 ProductionCrate Source and Target Media Types*

All media routing within ProductionCrate is built on the concept of a media playlist. Each media source is stored in the ProductionCrate data-store as an entry that references the location of the content. A playlist aggregates a list of these database items related to a playlist title for easy management and retrieval. All routing of media to a target renderer is performed by the target requesting the contents of one or more playlists. The target device is then expected to retrieve the list of items in the playlist and render them appropriately, and it is up to the client device how often a check is made for new playlist routings, and the content of these playlists. ProductionCrate implements a further feature to the traditional playlist implementation by including auto-generated playlists, similar to ‘Genius Playlists’ found in the iTunes[35] media player. These playlists related to a specific filter that is applied to the data store at regular intervals. Sources matching the filter are added to the playlist. ProductionCrate implements three types of auto-generated playlist that can be configured during an event:

i) Source type matching (e.g. “All Vetted Tweets”)
ii) Keyword matching (e.g. “travel”)
iii) Event matching (e.g. “Talk 1 @ 3:50pm”)

These playlists can be configured to retain only a sub-set of the matched entries, e.g. “the last 20 vetted tweets”. This facilitates a rapid turnaround on repetitive tasks such as vetting new tweets and them being routed to a display, avoiding constant intervention by the production crew. If an auto-generated playlist for vetted tweets is already routed to a display, all the director needs to do is vet the tweet in order to display it.

### *5.6.3 Video Streaming*

To support live streaming and recording of multiple video streams in multiple venues, I required a flexible, IP based video streaming solution. Rather than source expensive dedicated video encoding hardware to perform encoding, recording and distribution functions, I chose to deploy the open-source software-based alternative Flumotion[36], a Linux-based distributed streaming system that uses consumer-level desktop PC hardware. Flumotion is based on robust existing libraries including Python Twisted[37] for remote communication between software nodes, and the GStreamer[38] framework for video manipulation and encoding. Each video stream is configured from a central controller node on the network, which maintains the state of remote nodes. Remote ‘worker’ nodes need only to log into this central node to receive and carry out tasks such as video capture, video encoding, video streaming or video recording.

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[35] http://www.apple.com/uk/itunes/

[36] http://www.flumotion.net/

[37] http://twistedmatrix.com/trac/

[38] http://gstreamer.freedesktop.org/

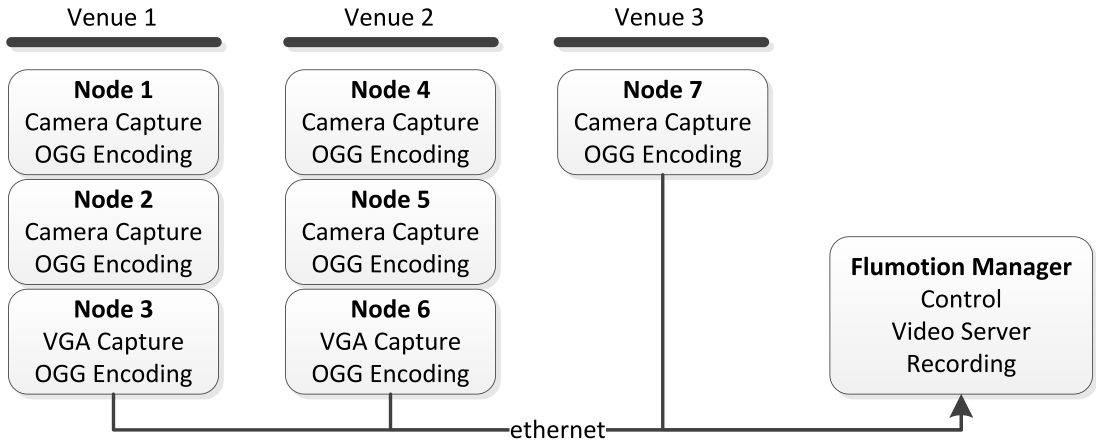


*Figure 29 Flumotion Nodes Configuration*

This distributed architecture allowed us to deploy a worker node for each video stream at the point of capture (i.e. in the talk venue), where a media source (camera or VGA capture card) would be directly plugged in. By performing the majority of the computationally intensive tasks (e.g. video encoding) at the point of capture, each video steam was reduced to only 400kbps from each node to avoid swamping network bandwidth. The controller operated a number of local 'workers' on the central Flumotion server that handled streaming to the rest of the ProductionCrate targets, as well as recording each stream to the file store. All system configuration was carried out from the control node without connecting or altering 'worker' nodes in the system (See Figure 30). Each worker node is a budget dual core PC running Mint[39] Debian Linux. Nodes for capturing camera footage include a FireWire card, and nodes for capturing presentation slides are fitted with a USB VGA capture device (See Figure 31). The use of multiple hardware and software tools as part of the ProductionCrate infrastructure required a widely supported video streaming format. I chose Theora Vorbis (OGG)[40] for its cross platform compatibility. A side effect of this decision was that both video streams and recorded footage were both highly compressed, and did not require large amounts of storage or bandwidth.

[39] http://www.linuxmint.com/

[40] http://www.vorbis.com/

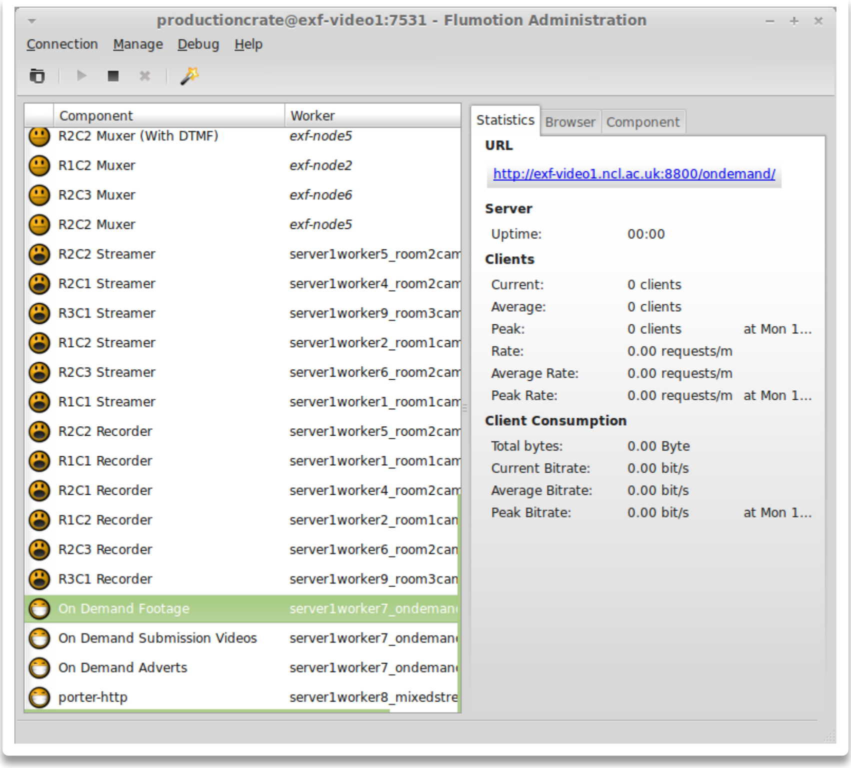


*Figure 30 Flumotion Control Application Running on the Primary Video Server: Displays the status of all Flumotion nodes on the network.*

*Figure 31 Flumotion Venue Nodes (Rack 1): Three rack machines – two for camera capture and encoding, one for VGA capture and encoding.*

### *5.6.4 Administration and Content Access*

Administration of the ProductionCrate system is performed through a web portal running as part of the ProductionCrate server. This portal is driven by custom software implemented in PHP, using the CakePHP MVC framework (Golding, 2008). Using web-based scripting language allowed for incremental and consistent additions as features were added during development. As a variety of platforms would be used to access the administration console, and to avoid unnecessary design for administration screens, the jQuery Mobile[41] framework was used, rendering a HTML5 User Interface in browsers that was compatible with mobile and desktop devices (Figure 32).

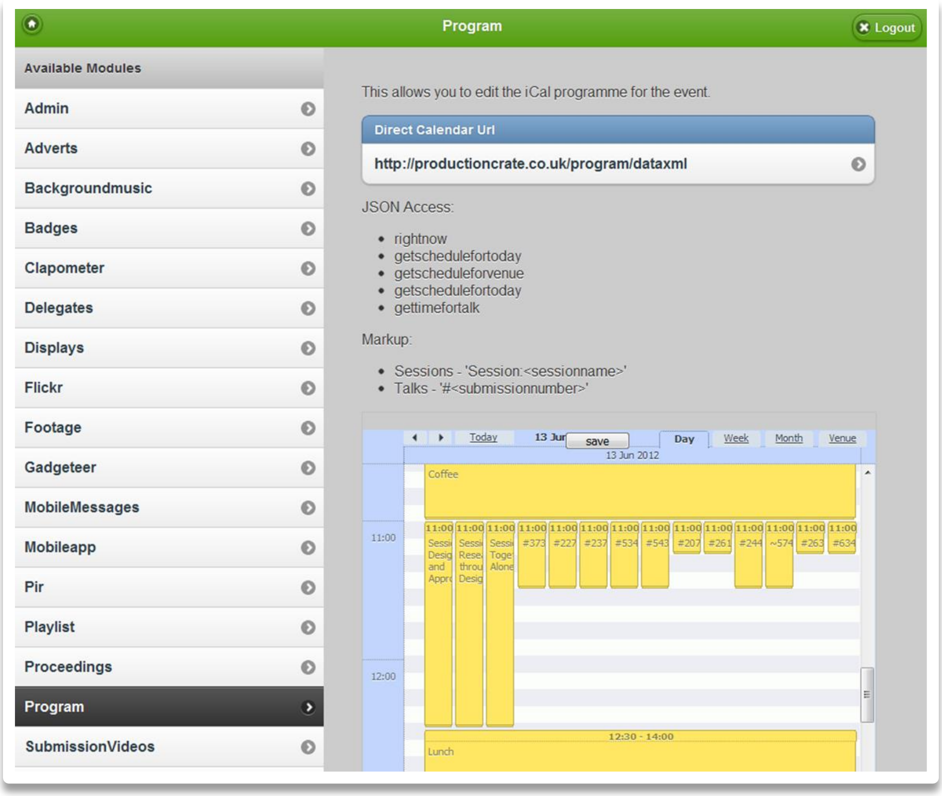


*Figure 32 ProductionCrate Administration Web Application*

A module for each source media type or administration area was implemented within a 'Controller' in the CakePHP 'Model View Controller' architecture. This facilitated the addition of new source media types and functions rapidly, and without large coding overheads. Controllers were written to aggregate social media streams and for administering static content. Data sources such as Twitter, Flickr and RegOnline[42]

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[41] http://jquerymobile.com/

[42] http://www.regonline.co.uk/

needed polling regularly to retrieve new content, and playlists needed regular updating to maintain current auto-generated content. These non-interactive tasks were carried out using a scheduled 'cron job' on the server.

### *5.6.5 Centralised Logging Infrastructure*

The ProductionCrate system consists of a large number of custom and consumer technologies positioned across a number of physical locations. To aid fault finding and software debugging without disrupting the attendee experience during the event, each element logs to a central server location. Logging has a well understood value for future development of systems, and in particular those involving user interaction, but in the case of ProductionCrate, this data may also be used as part of my empirical studies into the performance and use of ProductionCrate technologies. Utilizing the main ProductionCrate data store, simple REST commands were added to the ProductionCrate web API ('log', 'logmany'), enabling ProductionCrate-aware software to log both hardware events such as boot time and crash information, and individual user interactions. Each log entry includes a timestamp, event information, related software information and machine details.

### *5.6.6 RedTag*

A large amount of video footage was to be produced during the events. RedTag was developed as part of the ProductionCrate system to provide automatic content based meta-data for captured video footage. This meta-data would be available at various points in the production process, providing the production crew with valuable information regarding who is in particular a video shot. RedTag augments traditional video cameras and interactive surfaces with an infrared sensor which detects small electronic wireless tags mounted on attendees within the field of view of the sensor. RedTag consists of two key components, a transmitter (mounted on each person) and a receiver (mounted on a camera or interactive table). The RedTag system consists of multiple low-power infrared emitters, and rechargeable receivers (see Figure 33). Each small transmitter is programmed with a unique identifier (ID) and affixed to a person, object or at a fixed location. Receivers are mounted on camera equipment orientated in the same direction as the lens and connected to the secondary audio recording input. Tags regularly 'chirp', transmitting their ID via infrared. These codes reach the receiver only when within the camera field of view, are output as DTMF[43] tones representing the visible tag's ID, and are recorded onto the camera audio feed. Simple DTMF decoding software is used to return the ID and relative timestamp of each tag in the recording. RedTag specifically makes use of audible DTMF tones as a recording output so that existing (and non-professional) camera equipment can be used with RedTag meta-data. An additional audio channel (usually available as most recording only requires mono sampling) input into the camera is used. Audio watermarking was considered, but revealed to be in-appropriate due to the complex technical procedures needed to withstand unknown compression of the audio stream on different cameras and distribution networks.

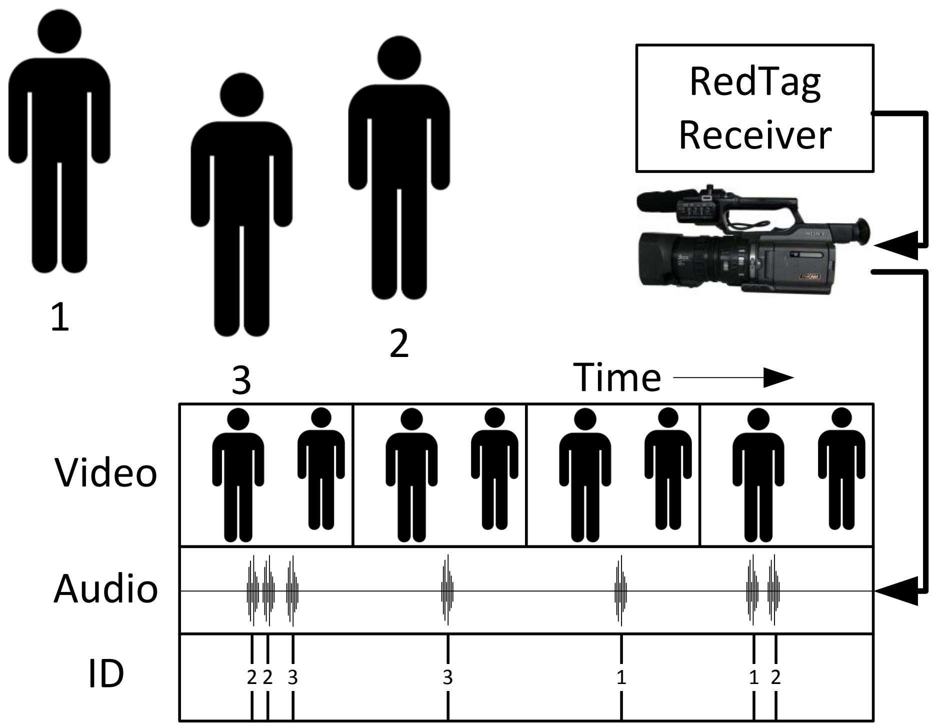


*Figure 33 The RedTag System*

RedTags use a modulated IR signal, similar to TV remote controls. Emitters are designed to be low cost, small consumables which can be embedded into objects. In one implementation, each emitter is powered by two replaceable coin-cell batteries, giving it a lifespan of around 3 weeks. In the most common configuration, a RedTag receiver emits each code that it receives from multiple RedTag transmitters as an

[43] http://en.wikipedia.org/wiki/Dual-tone_multi-frequency_signaling

audio DTMF tone, which is recorded onto existing audio recording hardware such as video cameras, or Dictaphone machines. A software application can then be used to extract the codes and timestamps from this recording as a text file in a post-production process.

### Transmitter

A RedTag transmitter (Figure 34) may consist of just seven or fewer components on a single layer PCB, including: a 6-pin 8-bit microcontroller, infrared emitter (850nm wavelength, modulated at 455 kHz), appropriate resistors and one or two coin-cell batteries. Even in small scale production, the unit cost for each transmitter is under $4, allowing transmitters to be used as non-returnable consumables in large scale deployments. During operation, the tag waits a pseudo-random interval (around 1 second) before transmitting its 16-bit payload (ID). This jitter prevents any tag's chirp from falling into phase with another and repeatedly colliding which would prevent successful reception. To prevent spurious or misidentification of tags, Manchester coding is used to transmit the payload, which helps to identify collisions with other transmitters. As an additional measure, the 16-bit payload consists of a 10-bit unique identifier and a 6-bit CRC (using the ITU 6-bit CRC) to protect against ID corruption. Given the 22.75 kbaud (455 kHz carrier, 20 cycles per bit), each 16-bit ID takes 14ms to transmit. Given perfect synchronization between transmitters this allows 71 transmitters to be detected per second. However, as no synchronization (or two-way communication) exists between transmitters or receivers, the collision rate increases with the number of transmitters visible. Through extensive testing, I have found that over 100 transmitters can be detected with an acceptable rate of collision, which allows for each transmitter to be detected around once every 5 seconds. By attenuating the transmitters in software or optically, the effective range of the transmitter can be adjusted from 5m to 100m, depending on the sensitivity required. Transmitter range is particularly directional and subject to multi-path reflection to receivers, however this can be advantageous when applying apertures to RedTag receiver units to match a camera's field of view.

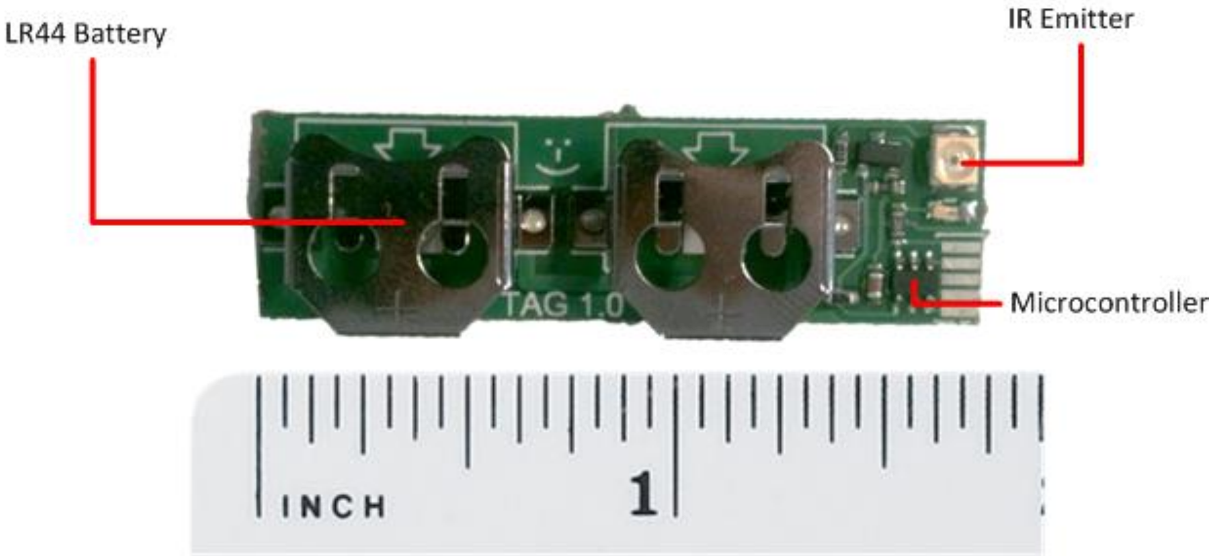


*Figure 34 RedTag Emitter*

## Receiver

Each RedTag receiver (Figure 3) features a 16-bit microcontroller, infrared receiver, a re-chargeable battery and combination 3.5mm audio jack and USB connector. The receiver has three distinct modes: DTMF[44] audio output, where the code for each tag received is output via the audio jack as DTMF codes; USB Serial mode, where the device emits each code as text over a USB serial connection; and Logging mode, where received codes are stored with timestamps on the internal memory. In DTMF mode, each code emits four DTMF symbols: a '#' symbol, used as a delimiter between records, followed by a three digit number. Each tone is played for 40ms with a 50ms interval, allowing three newly seen devices to be identified each second. The receiver operates a memory queue to buffer incoming codes, and ensures that newly observed codes are reported in a first-in-first-out order as soon as possible, and duplications in the queue have lower precedence than unique entries. Although using DTMF codes means that there may be a slight temporal delay between the receiver observing the device and emitting the DTMF code for it, this queue method ensures that all of the observed devices will be recorded within a temporally relevant period. To retrieve RedTag data from recording, the relevant audio channel is extracted and passed through a software DTMF decoder which outputs the ID and timestamp of each detected RedTag.

[44] http://en.wikipedia.org/wiki/Dual-tone_multi-frequency_signaling


*Figure 35 RedTag Receiver (in a camera mounted enclosure with an aperture matching the camera lens)*

I tested RedTag in a controlled setting to determine its spatial and technical limitations. In a single tag test, the effective range of a RedTag was tested to be 6±0.1m, and the effective angle of rotation from the receiver before losing signal was 185° from the horizontal. In two standard camera shots (close shot and mid-shot), with an F2.2 lens, RedTags are received within 2% outside of the camera frame bounding box, whereas in a wide shot, RedTags are only received within the centre 40% of the camera frame, due to the fixed sensor aperture. This makes sense as my receivers were configured for close, interview style filming. To evaluate the effectiveness in a real world scenario, I setup a 3 key use-cases as controlled tests: an interview or presentation scenario with 1 or 2 people in frame and a fixed camera; social coffee break scenario, with multiple small groups of people and a moving camera; a film acting style scenario, with a fixed camera, and acting towards the camera. For each one, I analysed: the **correctness** of tags (tag correctness, false positives; **temporal instability** (is the tag data recorded within a useable timeframe of sensing the tag); **maximum tags**; **range constraints** and **data accuracy** (e.g. missing people from clip). For the test, a single RedTag receiver was mounted underneath the lens of a Panasonic AF101 camera and plugged into the secondary audio input channel, and each of 11 participants wore a RedTag inside in a badge on a lanyard. 10 videos were captured in various filming scenarios. The tags from the resulting video were retrieved and compared against the same footage which had been annotated by hand to identify people in the camera frame. Overall, no false positives were experienced. In clips with a static camera and a single person in frame, their RedTag was received on a regular schedule (2s) throughout the clip. RedTags were prevented from detection by the user covering the transmitter. Whether deliberate or not, this prevented identification within the scene.

### Software

When using RedTag receivers in serial mode, each tag identification value is matched against attendee registrations from the database, returning the attendees name. When processing RedTag data captured on a camera video stream, the DTMF tones need to be converted into numeric values before database retrieval. A cross platform command line application is used to perform this task. Using ffmpeg[45] to split the right audio channel from the input video file; this file is then decoded into a raw PCM byte array and passed through a simplified version of the Goertzel algorithm (Goertzel, 1958). The result is a text file where each line contains the number of seconds into the video when the identification code was found, followed by the code. For live footage, Flumotion is configured to provide a two channel audio stream for recordings (including the DTMF channel), whilst stripping and creating a mono feed of the live footage for streaming without DTMF tones.

### Interactive Badge Tags

To capture meta-data about who is in each video shot for later use, each attendee wears a RedTag transmitter located in their conference badge, programmed with a unique code matched to their registration. This code can be used to identify and index attendees in videos taken by augmented cameras, which are used to record presentations and to film roving interviews with attendees throughout the conferences. Attendees have the opportunity to remove the tag at registration, or disable tracking by removing the badge or turning it to face towards their body.

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[45] http://www.ffmpeg.org/

*Figure 36 RedTag Emitter in a Badge and Receiver on a Camera*

## 5.7 Conclusion

In this chapter I described how academic conferences are embracing a growing trend of using socially driven and responsive multi-media content to engage attendees with an event. We were presented with an opportunity to host two events of this kind, but lacked the logistical and financial means to use a professional media production team and technology to support such a rich event media output. I developed ProductionCrate in response to this challenge. ProductionCrate is a suite of tools developed to support the production of dynamic media content during academic conferences. It is designed to support hybrid-attendees in performing production tasks whilst at the event, and integrates multiple media types and outputs to facilitate a directed media narrative of the event.

ProductionCrate draws on previous work that highlights the importance of social media and face-to-face engagement of attendees at a situated event, combining multiple consumer and bespoke technologies to provide an IP based infrastructure for delivering such an event. So far, I have described the design rationale and challenges associated with developing such a solution. In the next chapter I describe in detail the production tools that I developed within this infrastructure to support specific production tasks and how these were deployed and utilized during the two events we hosted.

# Chapter 6. Facilitating Directed Production

*WITH PRODUCTIONCRATE*

## 6.1 Introduction

The design of the supporting technology in Chapter 6 takes account of the spatially disparate nature of production staff across multiple venues at the conferences, to facilitate the delivery of high quality video and media content under typical budget and time constraints, through the use of consumer hardware, existing robust software libraries and bespoke interaction technology. The production and delivery of a responsive multi-format directed media production requires a specific production workflow of multiple steps. In this chapter I describe the key steps in this production workflow, associating them with roles that can be performed by the production crew. With these roles in mind, and building onto the infrastructure described in Chapter 5, I developed specific production tools that offer key elements of functionality to the production crew; I present these tools in terms of their technical elements, interaction design and specific interaction technologies chosen, discussing these designs in terms of the situational factors that impact on their use.

## 6.2 Engaging a Heterogeneous Team in Production

Designing production technology that supports heterogeneous teams performing production tasks presents a number of design considerations not traditionally supported by existing professional level technologies. Typically, each item of production technology is designed to support a very specific role or task within the media workflow, for example adding titles to a video stream. Within a professional team, each member of the team is a specialist in a particular area of the production process and the technologies that support it (such a sound recorder). These technologies require a particular level of skill and experience to operate effectively, qualities which hybrid-attendee team members will not possess. Tools that form part of ProductionCrate must be designed in anticipation of users with no prior skill with professional production equipment, and in particular the industry standard tool-chains and workflow practices used by professional teams.

Each hybrid-attendee will perform two distinct types of role during the event: as a member of the production team, and as an attendee. I can make use of this duality to improve the production process by acknowledging that as attendees (media consumers) they are in a good position to critique the output produced by the production team, feeding this back into their own practice to improve the output. The hybrid-attendee therefore creates an opportunity to produce content that is in some respects more salient and meaningful for attendees in general. However, the production tools that they would use to produce the content will be unfamiliar, increasing the cognitive load required to engage simultaneously in the content of the event and current production tasks. Continued disengagement in their production tasks because of such challenges may present as a problem if hybrid-attendees do not understand how their input into the production process is reflected in the media output of the event. As such it was key to support hybrid-attendees as stakeholders in the media production process, in which media that they helped produce became visible to the community through the directed narrative. In designing ProductionCrate, I aimed to increase a user's stake in the production by defining each production role as a self-contained production sub-workflow, each defining clear inputs and outputs that a crew member could respond to immediately. In turn, each sub-workflow was designed with a specific technology tool that simplified the complex production task and minimized the learning curve for the role. To drive continued engagement for each member of the production team, it was key to implement each new role as a self-contained production workflow, as in TV production, minimizing the learning curve for each task, and giving clear feedback regarding the result of their action in relation to the rest of the system. This workflow is displayed in Figure 37. Due to the compressed temporal nature of events like academic conferences, it is necessary to develop a rapid production feedback loop to keep social media and attendee generated content temporally current, especially without a collocated system of shared awareness to keep staff members engaged.

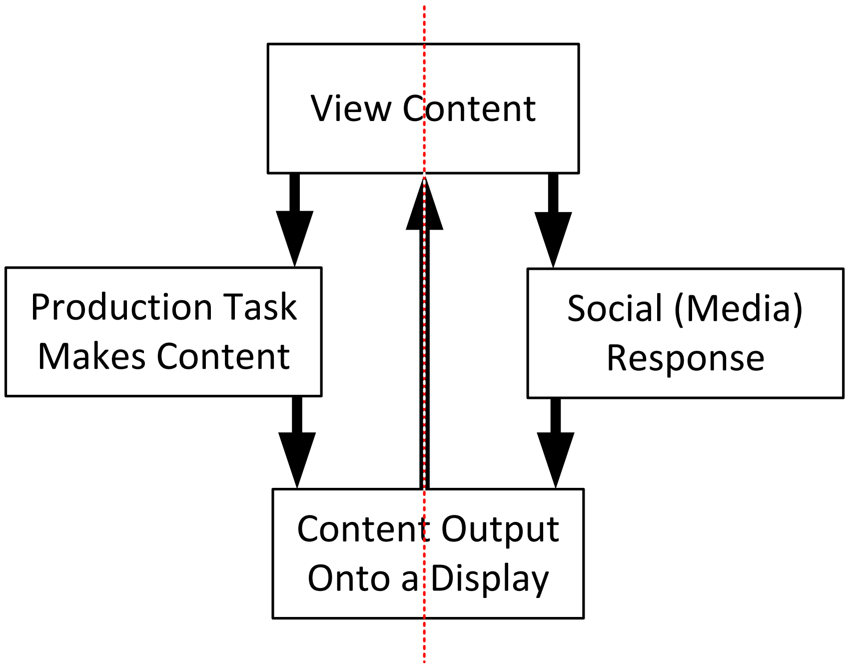



*Figure 37 The Production Feedback Loop*

Attendees are limited to the 'viewing content' and 'socially responding' phases of the production cycle, whereas hybrid-attendees, with the support of production tools, have the ability to influence the attendee experience by creating and influencing content through production roles as well as consuming media. To support this feedback loop, clear and responsive feedback must be provided while hybrid-attendees are performing production roles to maintain user engagement in the task. Each tool needs to provide an extremely rapid feedback loop from performing the task to recognising its effect on the media output, particularly as media might have to travel through multiple smaller workflows (and people) before distribution to attendee-facing media outlets e.g. creation, vetting, grouping and routing. Reducing the time that dynamic content takes to pass through phases in the production workflow during the event keeps media temporally and contextually relevant. Larger, more complex production tasks such as video editing can consume more time and technical resources than others (such as adding meta-data to clips). These larger cognitively loading tasks can be split into multiple sub-tasks (Maechling et al., 2005), distributed amongst multiple members of the production team, each of which can be performed independently. For each sub-task I can provide a tool, self-contained workflow and feedback loop to reduce the amount of time and new skills needed to perform.

## 6.3 The Production Workflow

To design tools that support novice crew members in professional level production tasks it was necessary to clearly understand what comprises a workflow for a responsive directed media production. Drawing on existing research of similar production workflows (Bartindale et al., 2009a; A Engström & Esbjörnsson, 2007; Zettl, 2011) and my own tacit knowledge as an expert user in the domain (Kientz & Abowd, 2008), I identified a set of production tasks which needed to be supported to maintain a multi-media production in a COI event. Hybrid-attendees are constrained by the amount of time available to learn complex new tools and to perform production roles whilst also participating in the event. These production tasks were aggregated such that they were performed by team-members fulfilling four distinct and independent roles: *production*, *grouping & vetting*, *maintenance*, and *direction*. A hybrid-attendee would be associated with one of these roles for the duration of the event. Distinct areas of responsibility and functionality were defined for each, resulting in a set of requirements for technology to support each production task. Hybrid-attendees are in many cases likely to have experience and be engaged in traditional conference organizational jobs, such as student volunteering, in addition to any production responsibilities, so by distributing tasks in the production workflow between team members, it is possible to balance the amount of work required for each production task, and ensure the practical availability of people to fulfil all the required production roles. For each production role, I define a set of production sub-tasks (or functions) which encompass the processes needed to support the production role. For each of these sub-tasks, I then describe a technology tool that was developed in response to the requirements of the task, and how this supports hybrid-attendees to perform the production role. Each of these tools is designed to support a self-contained production task and to provide clear feedback indicating the effect the crew member was having on the directed production workflow.

### *6.3.1 Content Production*

Content production is the initial workflow stage in which new media content is generated that will become part of the directed media delivery. This may include creating or collecting video, audio, image and textual information related to the event and the social conversation. A content producer's role is to output useable and complete content of a high production value into the ProductionCrate content store. This role encompasses the traditional role of camera operators, video editors and interviewers but in addition includes the pre-generation of content such as advertisements and notifications.

**Production Tasks**: (i) *Camera Operation*: with up to three cameras in each conference venue, camera equipment must be operated correctly, the picture quality controlled and the device infrastructure technically supported. After capture, each shot must be edited and added to ProductionCrate for immediate use. These shots include meta-data related to the shot to aid later routing decisions. (ii) *Interviewing*: to encourage discussion around particular topics that arise at the event, interviews take place with event presenters post-session. Relevant questions need to be asked even if the interviewer was not present during the talk, and the interviews captured using portable camera equipment. These clips are then edited, meta-data added and added to ProductionCrate.

**Technology**: (i) *Rapid Video Editor*: This table-top single-touch device is a simplified video editor. Producers insert memory cards from their roaming cameras into the device, which generates an editing preview. The producer can then drag in and out points on screen and add a small amount of relational meta-data (including related event program items). The unit then uploads any edited video to the server, for immediate use. Video footage of sessions from inside venues (immediately after a talk) can be viewed, in and out points rapidly set and uploaded for immediate use. Both audio and full quality video from any venue are accessible on the device. (ii) *Mobile Interview App*: A mobile HTML5 application is available as a handheld information portal for interviewers, camera operators and content producers. Abstracts, related Tweets, Flickr images, and questions related to a presentation are viewable. This can prompt interviewers with contextual information regarding the interviewee.

### *6.3.2 Content Curatorship*

Creating a responsive directed production requires the curatorship of attendee-generated media such as social media posts. These media feeds are often publicly accessible streams which require vetting to maintain both a high production value of content and relevancy. Once obtained from the original source, this content needs to be collected into playlists that respond to and drive the social conversation according to topic and venue location to make sense of the wider conversation. This role may include social bootstrapping or “Tweet seeding” (Solomon & Wash, 2012) to build a critical mass of content and curate social conversations towards particularly interesting or related topics. Conference Chairs are well placed to take on this role during the event as they are typically not involved in logistical event management. The presentation Session Chair can be considered a curator of media during the event, as they have editorial control over questions and answers during a session. This role requires a contextual understanding of the content being presented, and social skills to curate a discussion around these topics, as well as maintain the event timetable.

Production Tasks: (i) *Social Media Vetting*: To ensure only relevant and non-offensive messages are displayed publically, all incoming social media feeds (Twitter and Flickr) should be vetted and approved. On occasion this may involve selecting specific messages over others to be included as content in ProductionCrate if they have a higher contextual or temporal relevancy. These tasks must be carried out as soon as possible when content is received to achieve maximum production value and a responsive attendee feedback loop. (ii) *Social Media Bootstrapping*: Social media may need to be seeded with content to achieve a critical mass of involvement from attendees. This may include coordinating specific mentions of relevant social media feeds during session introductions, and necessitates an awareness of the current social conversation. (iii) *Session Chairing*: A session should be chaired by a well-informed and assertive member of the team who maintains event timings and curates live discussions.

**Technology**: (i) *Tablet Controller*: Incoming social feeds are displayed in a tablet application. Messages are viewed and then approved by selection from a list. Playlists of content can be built around specific items and by automatically searching for keywords or items that are related. These playlists are then available for use as groups of pre-determined content. (ii) *Talk Timer*: A tablet held by the Session Chair during presentations, that displays timing and timetable information. Current social media is filtered onto this display according to the event for contextual framing of backchannel conversation to aid discussion chairing.

### 6.3.3 Maintenance

Large volumes of media need to be aggregated from multiple sources throughout the duration of the event. Much of this data is superfluous or irrelevant due to its content or type and will be removed during the Vetting process. For the remaining media, relationships can be explicitly created between items of content such as Tweets that related to a particular presentation, providing meta-data that aids directorial decisions for routing of content. The maintenance role is responsible for building these relationships and maintaining the production quality of event media. I chose to augment the student-volunteer role, typically associated with venue logistics, with this production role, particularly as volunteers would be present across all presentation venues.

**Production Tasks:** (i) *Content Relationship Creation*: Content, especially social media can relate directly to elements of the program or proceedings. Relations between content are used in later production processes by the Director to make media routing decisions, and by interactive applications such as touch-tables for navigating related content. To create useful relations, the operator must be able to understand the content and context of the media to make appropriate choices. (ii) *Meta-Data Creation*: Relations require media to be present in the ProductionCrate system. Most types of media are already digitised and aggregated automatically from available sources (e.g. Twitter) but some useful information such as questions that are asked during Q&A sessions are not. This data may need to be entered manually into ProductionCrate for association with other media.

**Technology**: (i) *Web Relations Manager*: A web interface available on laptops or tablets inside presentation venues allows student volunteers to record Q&A sessions as they occur. Recent Tweets are displayed alongside each presentation, and each can be assigned to specific presentations in a session.

### 6.3.4 Media Direction

The Media Director role is key to the curation, delivery and maintenance of conversations during the event. This role differs from the Event Director (Production Manager), whose role it is to oversee the delivery of the event as a whole entity including all attendee facing aspects of the event (such as catering, logistics). The

Media Director, however, makes decisions regarding content routing and display, timings and content theme. Aspects of this role can be distributed amongst knowledgeable crew, including conference Chairs and long standing members of the COI, who have intimate knowledge of the people and topics involved.

**Production Tasks**: (i) *Media routing*: Making complex content routing decisions and directing media to multiple destinations whilst supporting a responsive and socially aware content output. Multiple media types and output devices must be considered, along with the overall program and timings of the event and the contextual relevance of available media. The Director is responsible for maintaining a coherent narrative and has editorial control over content and the media output of the event. Although complex, in contrast to StoryCrate, this role can be delegated to trusted members of the team when needed, or be distributed across multiple team members.

Technology: (i) *Tablet Controller*: Carried by a director anywhere on site, this wireless tablet interface provides an overview of the event from a timing, social and aggregated media perspective. This interface links directly to talk timing devices, displays the status of ProductionCrate hardware, and provides a content routing service for the director. Content routing is performed on a simple thumbnail-based interface using two-finger gestures, placing one finger on the source and destination to perform a routing.

## 6.4 Production Technology

For each of the production roles in the workflow I have defined technology tools that facilitate hybrid-attendees in performing key technical tasks for the production. Each tool was developed to support a succinct and discrete element of the production workflow for the hybrid-attendee operator, whilst providing appropriate contextual information about the current state of the production across the whole event according to the role. Each tool was designed in response to situational factors most affecting each role as well as: to reduce cognitive load on the user, allowing them to participate in the event as attendees; to provide tools that simplify complex production tasks; and to allow crew members to drop in and out of their production roles efficiently. Interaction technologies were utilised in each tool to support specific requirements of the corresponding role (such as mobility). Some production tasks require the operator to be situated in specific parts of the venue (e.g. in a presentation session). As the team is distributed across the venue in multiple locations, ProductionCrate is to be used in conjunction with a broadcast voice communication system connecting the production team wirelessly. This supports back-channel team communication, error reporting and logistical messaging. As ProductionCrate encompasses a range of hardware and software solutions, I decided not to create a communication system as part of each production tool, instead making use of a robust existing technology (radio) which many members of the team would already be familiar with.

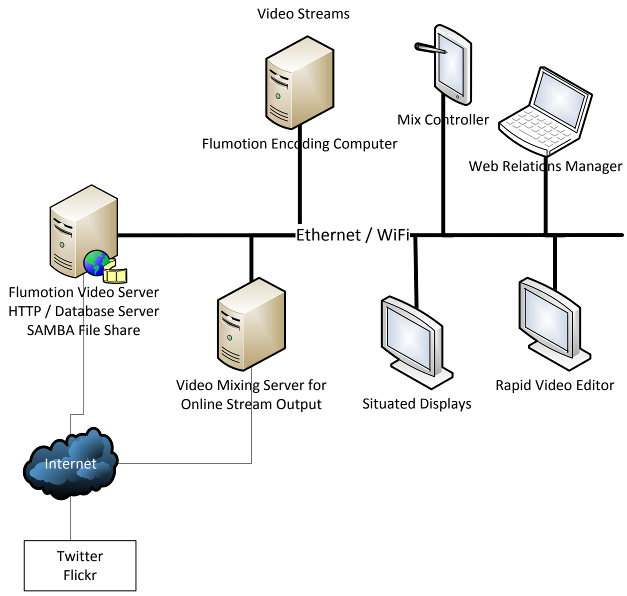



*Figure 2 The ProductionCrate Ecosystem*

### 6.4.1 ***Rapid Video Editor*** *(operator: Content Producer)*

The rapid video editor is located in the venue and provides simple ingest, editing and uploading facilities to Content Producers. It consists of an interactive table-top in which a single touch display screen is mounted at an angle of 30° from the horizontal surface (designed to be operated whilst standing). The unit contains a standard Windows 7 PC, and includes headphones, Ethernet and an integrated media card reader in addition to a 22” single touch capacitive display.

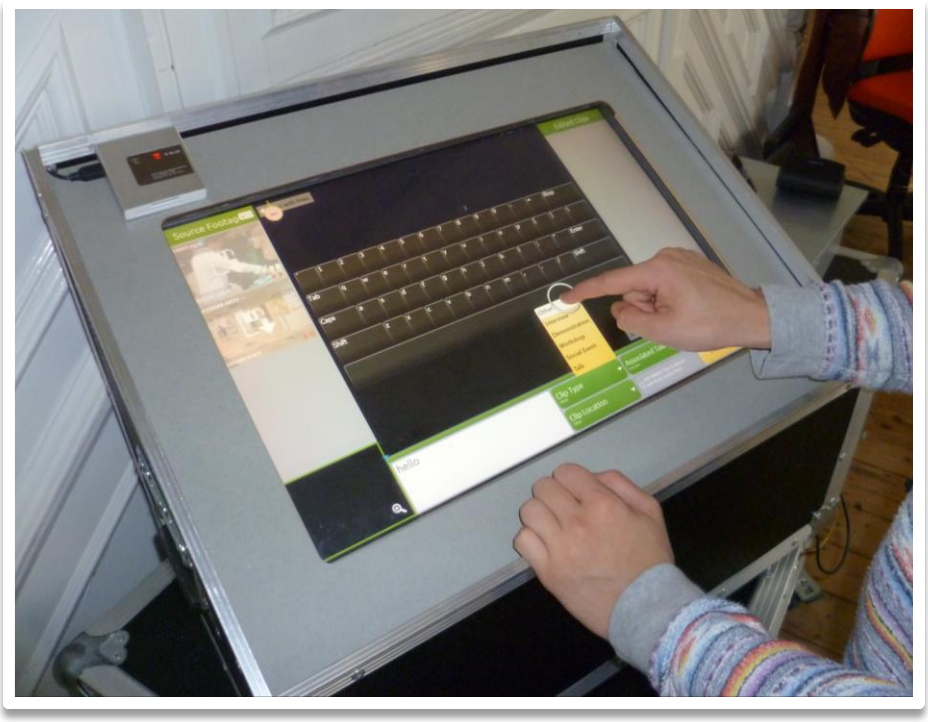


*Figure 38 Rapid Video Editor*

The rapid video editor provides a simple five step video editing interface for editing video content quickly and efficiently:

1. **Clip Ingest:** When not in use, the editor displays visual cues for inserting a media card into the reader, or selecting video clips that are already in the ProductionCrate system and need editing. Clips are ingested regardless of the camera technology or recording medium. When either inserting a card or selecting the server option, clip thumbnails are downloaded from the target location and displayed in a list. Selecting a clip downloads it locally for editing, producing a Panopticon version of the video (Figure 39), displaying it in the central area of the interface (Jackson & Olivier, 2012). Panopticon is a video summary technique which generates a looping thumbnail video containing the entire source clip. Server clips from multiple cameras in the same venue are "stacked" together within a single media source, appearing as single clips with multiple angles to be edited. These can be switched between when editing, and when edited clips are processed, all cameras will be processed with the same in and out points.

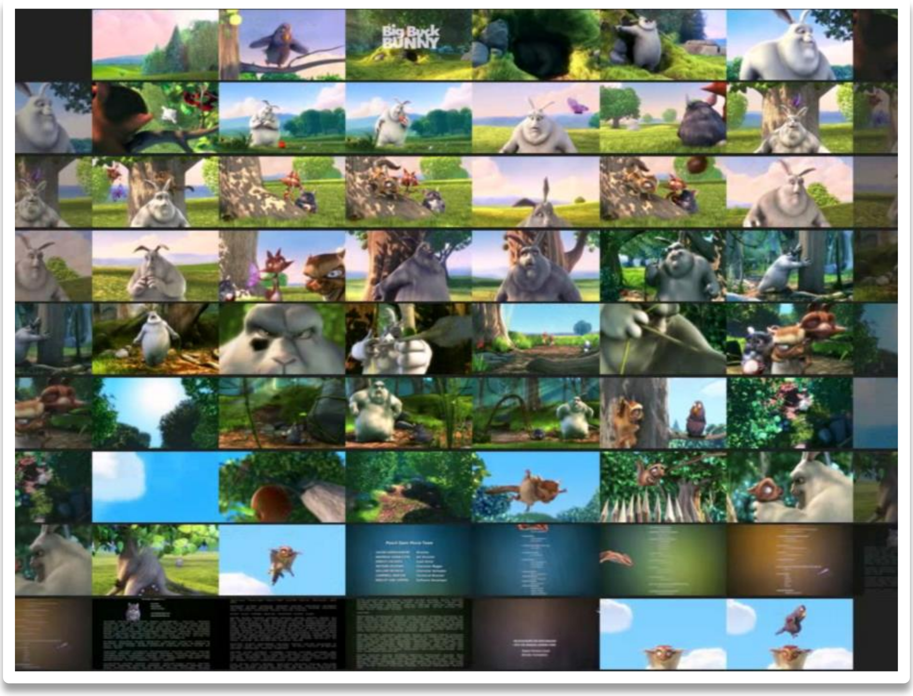
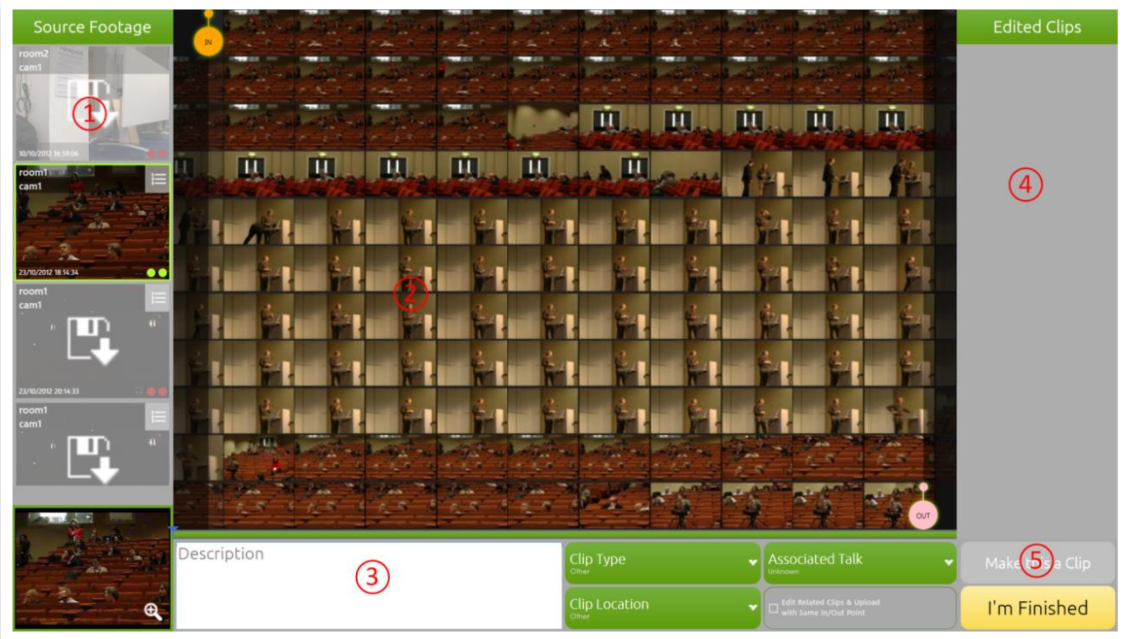



*Figure 39 A Panopticon Rendering of a Source Video (Big Buck Bunny, Blender Foundation)*

2. **Viewing annotated meta-data:** When a source clip is first viewed, meta-data from the server is downloaded and displayed on the preview screen as small coloured markers overlaid over the Panopticon video. Available loaded meta-data includes: RedTags in shot (and the names of associated attendees), talk timer events (start / end of presentations) and social media that was submitted within the same timeframe (Twitter). Selecting a marker reveals more detailed information about a specific meta-tag. The operator can use this information to make informed and rapid editing decisions without contextual knowledge of the specific recording.
3. **Editing In and Out Points:** In and Out markers can be dragged around the preview screen for a source clip, snapping to the rows of the Panopticon view. A play-head is overlaid on the preview, and playback in a smaller window loops between the in and out points set by the operator.
4. **Adding Custom Meta Data:** Once the clip range has been chosen, a few simple input elements provide a method of adding related user-generated meta-data, including: a short textual description, a related presentation (from a given list downloaded from the ProductionCrate server), and the type and venue location of the clip.

5. **Saving Clip:** When satisfied with a clip, the operator can create an edit. This uploads the selected portion of the clip, with associated meta-data, to the ProductionCrate server. This is realised as a background process, allowing the operator to continue editing clips or close the application. Multiple clips can be made from the same source footage, but once a source clip has been made into at least one clip, a file is created which removes this source clip from future listings of the target media to prevent accidental editing of duplicate clips. To avoid long loading times while waiting for file transfers, original sources files are only copied and processed by Panopticon on selection, and only the first 10 non-edited files are displayed in the selection list.




**Key:** *1) source footage appears here, selecting items downloads locally for editing, 2) Panopticon video representation with edit handles, 3) meta-data can be added using free text or lists of existing data, 4) clips selected for output are listed here, 5) user clicks to create an edit of the current clip.*

*Figure 40 Rapid Video Editor Screenshot*

### 6.4.2 *Mobile Interview Application* *(operator: Content Producer)*

The mobile interviewer application was designed to be used by any member of the production team through their personal smart phone whilst moving around the venue, connected to the venue Wi-Fi network. A URL provides access to a mobile-device compatible sub-site of the primary ProductionCrate administration console. The application provides three simple views with which the user can rapidly find and access information pertinent to the interview they are about to perform. Figure 41 shows these three sections: Search, Person View and Paper View. The search view displays a list of all authors and all talks that are part of the event. Search boxes allow the user to filter the list by typing initial characters. Selecting a particular person displays the Person View section just as selecting a particular talk displays the Paper View section. The Paper View section displays a compact and easy to digest set of information about the selected paper and talk. The title, authors and abstract are key for the user to check it is the required selection, but are also useful if the interviewer has no direct knowledge of the selected talk. In addition to this static information, the date, time and presenter of the talk are displayed. The remaining area of the screen is taken up with the social media and questions asked during the talk. The interviewer can use these to guide conversation or continue from previously asked questions that require more time to answer. The Person View displays a list of associated talks and paper submissions for the selected person, for the user to navigate to a specific talk when approaching a particular person before an interview.

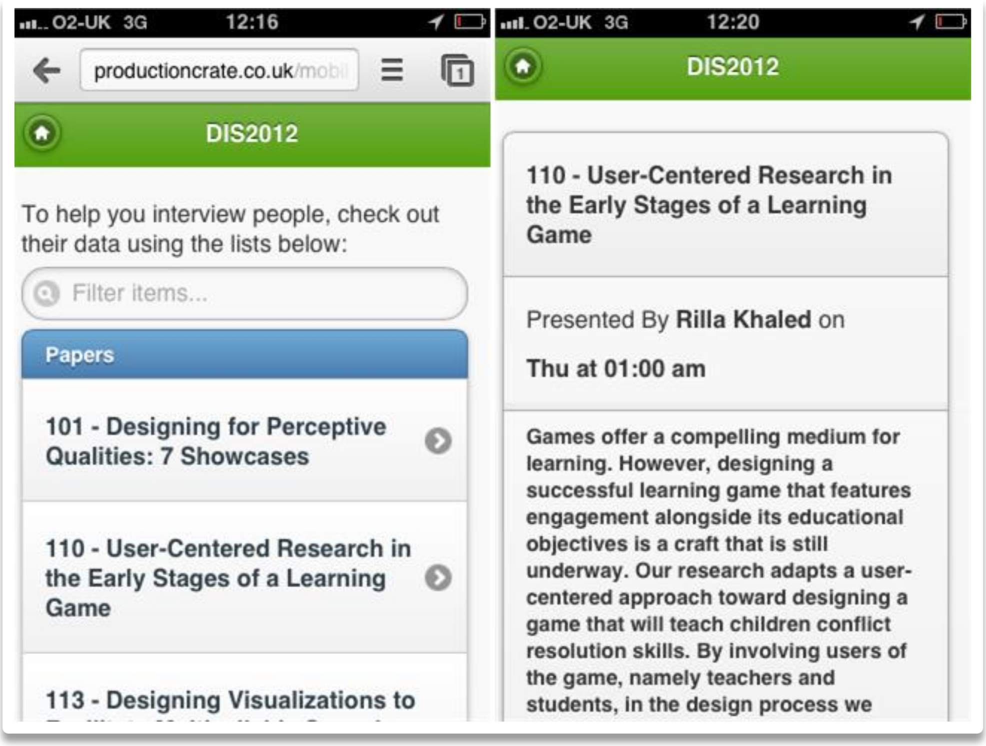



*Figure 41 Mobile Interview Application*

After a presenter has given a talk, ProductionCrate automatically emails the presenter a list of the questions asked during their presentation and any related social media. This email suggests that the presenter may be asked for further comments and discussion on these topics. In this manner, both the interviewer and interviewee are forewarned of the possible areas of discussion.

### *6.4.3 Tablet Controller* *(operator: Director and Content Curator)*

Each tablet controller is deployed on an 11" Acer Iconia Tab W500 tablet PC with a Windows 7 operating system. These tablets connect to the ProductionCrate network using inbuilt Wi-Fi capability allowing use throughout the event venue. The tablet controller software is written in .NET 4 and WPF for user interface design, and Windows Communication Foundation (WCF) libraries for communication with the Web Stream Mixing Servers. Using WCF enables both rapid communication between devices, but also a transparent native language interface (C#) which includes connection failure recovery, fault tolerance and non-polled duplex communication. As in the attendee-facing tabletop programme, media in ProductionCrate is represented as a thumb-nailed tile in the interface (all outputs are similarly represented). Either a single finger drag gesture or a two fingered gesture, placing a finger on the source and one on the target, routes source content onto targets. This enables rapid one-handed changing and routing of content, which is necessary for when the operator is walking or moving around the venue. Again, as in the tabletop interface, media can be previewed full screen by performing a touch and hold gesture on a specific thumbnail. VLC is used to render video streaming from the server. Since the tablet interface can store and visualise all of the content present in the ProductionCrate data-store, a direct connection to the MySQL server is used. To avoid unnecessarily large database data transfers, polling is conducted at a range of frequencies, for social media (polled every 3 seconds), through to static content (polled every 5 minutes). Split into a tabbed interface, there are three key sections in the application: Vetting, Routing and Playlist management. The interfaces in these three sections are described in Figure 42.


***Key:*** *1) list of playlists to edit, 2) items available in the system, and filter functions, selecting an item adds it to the current playlist, 3) items in the selected playlist, 4) items available for routing, 5) destinations for routing. Routing is performed by dragging items to destinations or selecting both simultaneously. 6) list of un-vetted social media content, 7) list of vetted media content. Selecting items in either list toggles their vetting status.*

*Figure 42 The Tablet Controller Interface*

### 6.4.4 *Web Relations Manager (operator: Maintenance)*

The web relations manager is a web-based HTML5 application accessible through a web browser. Operators are encouraged to use their own mobile device or laptop to access this system for operation during a presentation session. This reduces the requirement for centrally managed equipment, and allows operators to use a variety of tablets, laptops or mobile devices in fulfilling their role. On initial entry to the application, the current venue must be selected, after which the application presents a display divided into two sections: a list of the ten most recent Tweets from the social media feed, and a list of the talks being presented in that venue on the current day. The interface facilitates two primary tasks during a session:

1. Selecting a Tweet which has been retrieved by ProductionCrate from the Twitter API, and then clicking on a talk on screen to relate this Tweet directly to the talk by adding a database entry to describe the relationship.
2. Under each talk on the screen is located a list of the questions asked during that talk. New questions can be entered into the text box below this list by the operator and are added to the ProductionCrate system as related media to the presentation.


*Figure 43 Web Relations Manager Screenshot*

To avoid overwhelming the user with information, the list of Tweets is limited to the ten most recent which have not been related to any talks. If a Tweet is not considered to be relevant to any talk, it can be hidden from the list by selecting the ignore option next to the Tweet. The application is designed to be used with a touch screen or track pad device by incorporating large controls for touch, and a drag and drop gesture for Tweet relations.

### *6.4.5 Talk Timer (operator: Content Curator)*

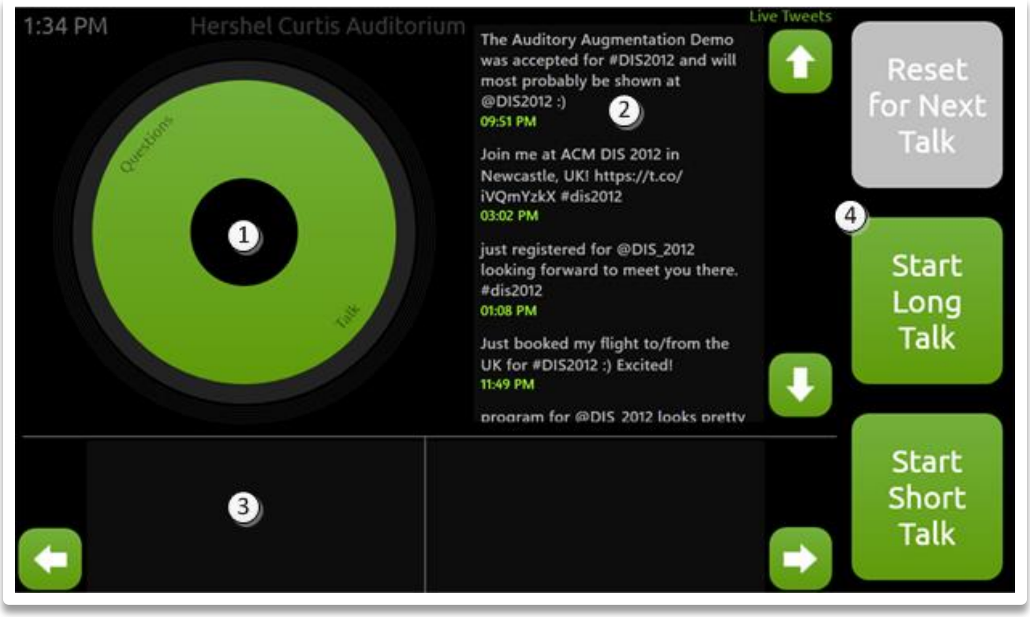
By integrating key event management activities such as time management into ProductionCrate, we can drive responsive content directly from real-time event timings. Timing information can be used by the Director to inform editorial decisions for routing content-specific data to situated displays, and by Content Producers to edit footage. I developed a talk timer device for presenters and session Chairs, to support accurate time keeping within sessions. The talk timer provides an interface for the session Chair that records the real-time start time of talks within the session. Additionally, this tool addresses the failure in time keeping often seen during academic conferences by providing a shared view of a talk's progress between the speaker and session Chair. Following my approach of making conference data visible to attendees, talk progress was also made available through an ambient display visible to the presenter and partially visible to audience members. This device displayed information about the progress of talks within the venue whilst displays situated outside the venue displayed the timings and current programme with information drawn from the talk timers. A tablet PC located with the session Chair allowed them to trigger and indicate the beginning of a new talk and subsequently monitor a countdown timer. For the presenter, a strip of five lights next to the podium would light up in sequence as the talk progressed, where each light was labelled with a different amount of remaining time. When the speaker's allotted time had passed, the lights flashed repeatedly to attract their attention. The audience could also see these lights through the back of the device, although they could not see the labels showing exactly how much time was left. An ambiguous display of the time remaining is desirable to give an impression of time remaining but without an accurate number which would encourage people to leave the session early.

*Figure 44 TalkTimer Hardware*

Each TalkTimer consists of a small tablet PC running Windows 7, along with a powered USB hub attached to a custom built display stand. The display stand is CNC milled from oak and walnut, and presents the users with 6 LEDs mounted vertically behind frosted acrylic. Markings on the front surface indicate time remaining associated with each LED. The LEDs are connected to a Phidget 888[46] interface board mounted in the base of the stand. The rear of the LEDs are visible through frosted acrylic to the audience.

The tablet runs a WPF application which presents the user (session Chair) with a simple control interface for running the timer, shown in Figure 45. The interface displays incoming Tweets from the ProductionCrate data store, as well as the current and future programme for the venue the TalkTimer is installed in. At each point a talk is started on the timer, the time, talk length and venue are uploaded to the ProductionCrate server for use by other ProductionCrate systems such as displays and Control Tablets.

[46] http://www.phidgets.com/




**Key**
1. Pie-chart countdown timer, 2. Latest Tweets, 3. Current and next talk information, 4. Three control buttons.

*Figure 45 TalkTimer Control Tablet Interface*

### *6.4.6 Integration into the Workflow*

Operators of these technologies must react to new media as it is dynamically created, whilst using static and older content to build a cohesive story for attendees which relates to their current experience of participation in the event, presenting this narrative through the audience-facing technology of ProductionCrate (Figure 46). These production technologies were designed to facilitate the production feedback loop with attendees, and as such both consume data from the server media repository, and feed new media back into the system for use by other devices (return arrow in Figure 46). To facilitate a coherent representation of the event that can be provided to all ProductionCrate tools, a fine grained representation of the event timetable is stored on the ProductionCrate server. This allows venue-wide responsive timetable changes to be made at a central location, updating all the appropriate tools accordingly and allowing automatic playlists to aggregate the correct content for situated displays.

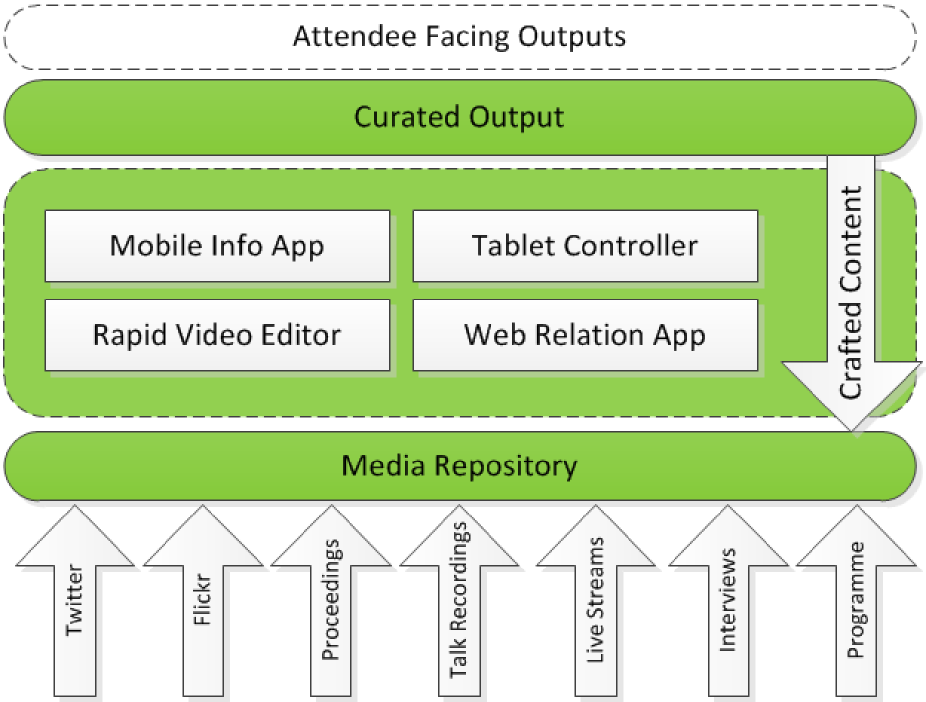



*Figure 46. Repository Server Architecture*

### 6.4.7 *Design Aesthetics*

In line with my experience of developing production technology for professional users for StoryCrate, ProductionCrate production tools were designed with a specific 'event technology' aesthetic throughout. The use of heavy duty flight-cased equipment was advantageous both practically and aesthetically, especially as some of the equipment was to be used in amongst the attendee areas, and would be transported between venues during the event. By creating equipment that looked 'technical' and 'professional', normal attendees would be discouraged from experimenting with the technology, whilst the flight-cased appearance added a level of professionalism to the event. This professional aesthetic encouraged hybrid-delegates to respect the value of the equipment in terms of its effect on the event (and therefore the ability for it to drastically affect other attendees' experience) and made them feel valued within the event organisation (worthy of professional equipment). By combining familiar interface technology such as touchscreens with production technology styling, hybrid-delegates were able to operate technology that was both robust and easy to learn.

## 6.5 Conclusion

In this chapter I described in detail the challenges for designing tools that support heterogeneous hybrid-attendee production teams. In particular, I discussed reducing cognitive load by distributing production tasks amongst the production team, and the need for self-contained feedback loops for each production task to engage users in the content production process. Drawing on previous research, I defined the production workflow and roles required to administer such a responsive media output for academic conferences. For each of these roles I describe the production tools that I have developed as part of ProductionCrate to support each production task. In the next chapter I outline the deployment of the ProductionCrate system at the events my institution hosted, and discuss the design of these production tools in response to the challenges of hybrid-attendee production.

# Chapter 7. A Responsive Media Conference

*WITH PRODUCTIONCRATE*

## 7.1 Introduction

ProductionCrate was designed with the overall goal of supporting COI events; but also in response to the requirements of two specific international academic conferences held in Newcastle upon Tyne, UK. These events are prime examples of events which are impacted by a range of situational factors common to COI events. In this chapter I describe the deployment of ProductionCrate in those two academic conferences, highlighting the logistical decisions that were made to support the ProductionCrate workflow and the technology deployment configuration. Through post-event interviews with hybrid-attendees who were part of the production team during the deployment, I analysed what influence ProductionCrate had on the production workflow and the provision of a directed media output for the event. Inevitably, this initial analysis revealed the shortcomings of organising a large situated event alongside the development of new media production technology. I describe these issues and provide an account of an additional deployment at a subsequent academic conference event in Aberdeen that allowed me to deploy targeted elements of ProductionCrate with a view to refining my understanding of these tools. Through a journal-led account of this experience recorded by the production team at the event, I draw together more systematic descriptions of ProductionCrate's supporting role in the production workflow that builds on my findings from the Newcastle events. Finally I use a thematic analysis from my two deployments (Newcastle and Aberdeen) to inform a discussion into the design of ProductionCrate and how it supported the production of situated events using hybrid-attendee teams. Through this discussion I present specific design considerations for building tools to support a hybrid-attendee production workflow and present findings that can be transferred for use within other COI events which share similar situational factors.

## 7.2 Newcastle Deployment

ProductionCrate was deployed throughout the two-week period of the ACM DIS 2012 and Pervasive 2012 conferences in June 2012, hosted on the campus of Newcastle University in Newcastle upon Tyne, UK.

### *7.2.1 Production of an Academic Conference Event*

Each conference had two initial days of workshops with limited opportunity for attendees to mix with each other, followed by three days of main conference presentations and evening events. Each main conference day was organised along the lines of a conventional academic conference, with four ninety-minute sessions, each comprising three or four presentations and question and answer sessions (following each presentation). Three sessions ran in parallel (as independent 'tracks') across different presentation spaces. Coffee breaks were taken in the lobby area surrounding these venues, but lunches were served in an additional venue (away from the presentation venue and main foyer). An evening dinner and demonstration evening were organised in the evening of the first and second days of the main conference.

**Technology Deployment**

ProductionCrate technologies were deployed in each event space, that is within presentation spaces and in foyer areas (see Figure 47).

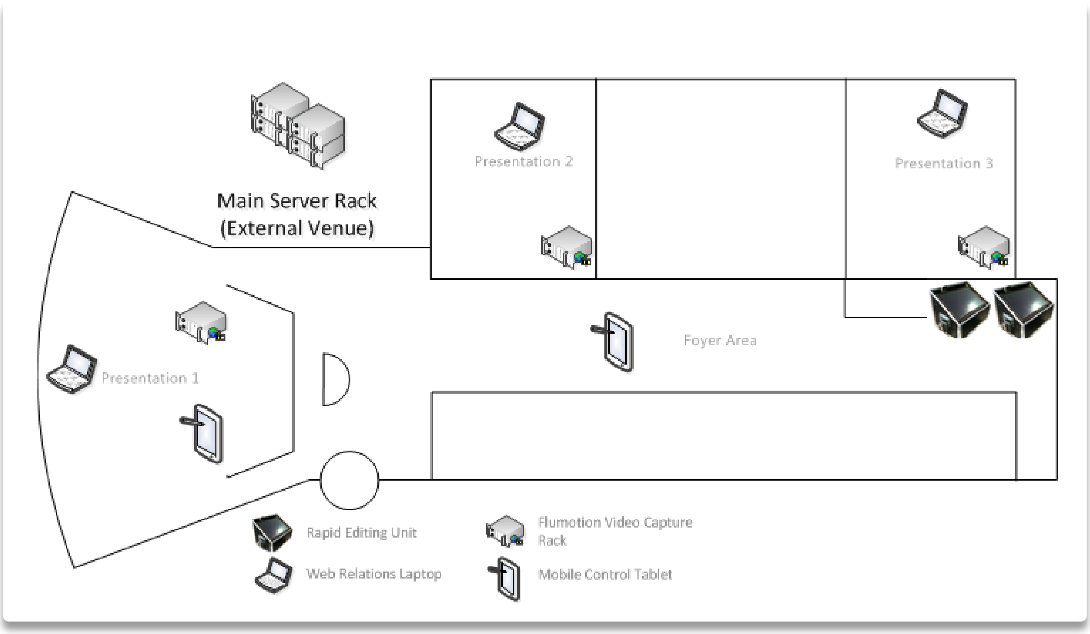



*Figure 47 ProductionCrate Technology Deployment across the Conference Venue*

Supporting infrastructure such as networking, servers and large-scale equipment such as TV displays, Rapid Editing Units and camera equipment were deployed in a 12 hour window before the conference venue was open to the public. Whilst attendees were attending workshops in the two days of the conference, smaller elements of technology were brought online, such as Talk Timers, Tablet Controllers, and roaming camera equipment. In each of the three session venues we recorded and streamed three live video feeds (two cameras, presentation), installed a laptop for the Content Maintenance role, and sound and lighting equipment. We deployed a camera operator, session Chair, venue controller (technical support) and student volunteer in each presentation venue during each session to provide technical support and to operate the equipment. Whilst presentations were happening, a conference Chair performed the Content Curatorship role using a tablet controller, while another performed the Director role with a second tablet. During breaks, a camera operator and interviewer were tasked with producing video interviews (with attendees) and editing them on one of two Rapid Video Editors deployed in the foyer area.

### Attendee-Facing Media Consumption Technology

The full range of the attendee-facing technologies outlined in Chapter 5 were deployed across the conference venues during the two week period of events. During this time 587 people attended the events, and the majority of these attendees would have come into contact with one of the attendee-facing technologies at some point. This figure excludes those who had only attended workshops (i.e. total unique attendees was 672), as only small portions of the technology were in use during these days. These technologies were deployed across the two venues that were most often frequented by attendees, in places where breaks and lunches were taken and inside presentation venues (see

Figure 48). Advertising was located throughout the venues both in print and via the event TV channel, informing attendees of the interaction opportunities available through these technologies and the relevant social media channels with which to engage (Twitter and Flickr).

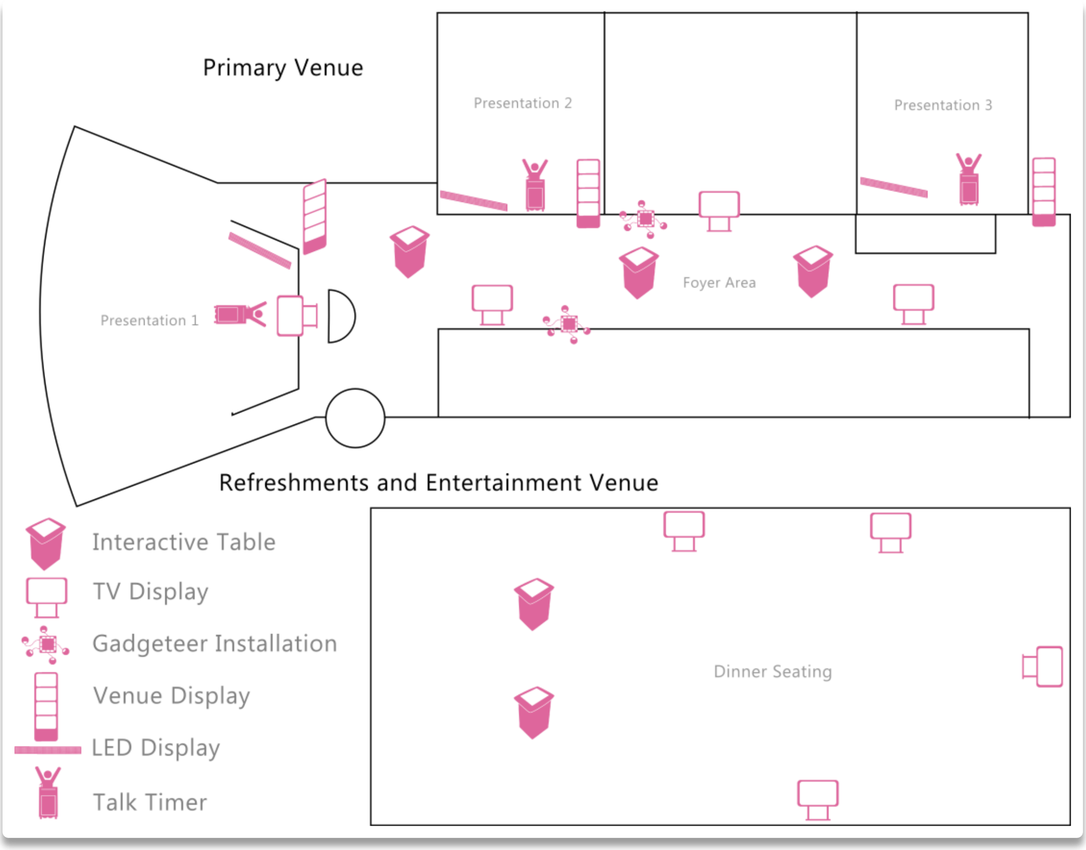



*Figure 48 Map of Attendee Technology Deployment During the DIS and PERVASIVE Conferences*

Each of the three presentation spaces contained a scrolling LED display and a Talk Timer. Six Interactive Tables were placed in social areas of the venues, along with twelve TV channel displays. A conference mobile application containing the event schedule was available to download from the Apple and Android mobile app stores.

## The Production Team

A team of staff from Newcastle University carried out the majority of typical event organisational roles, and for the most part were engaged due to interest in the event topic as well as relationship with the institution. These staff were mostly tied to the specific physical locations and roles throughout the venue, listed below:

- Sound reinforcement support (referred to as the Venue Controller) based in each of the presentation rooms.
- Session Chair, based in each of the presentation rooms.
- Registration Desk Support, based in a central location.
- Microphone Handlers (traditionally carried out by student volunteers), based in each of the presentation rooms.

- Camera Operators, one or two based in each presentation room.
- Logistics, based centrally but required to move between venues and rooms as required in a response role.
- Conference Managers, based at the registration desk, moving as required.

In addition to these common conference-related roles, this same team was tasked with fulfilling the production related roles using ProductionCrate. Combined with conference Chairs and knowledgeable attendee volunteers, this group made up the hybrid-attendee production team supporting the event. Within this group, a management hierarchy was established so that problems and queries were dealt with quickly and by the appropriately knowledgeable staff member (Figure 49). This team ranged between twelve and twenty-five people on site at any one time during the event.

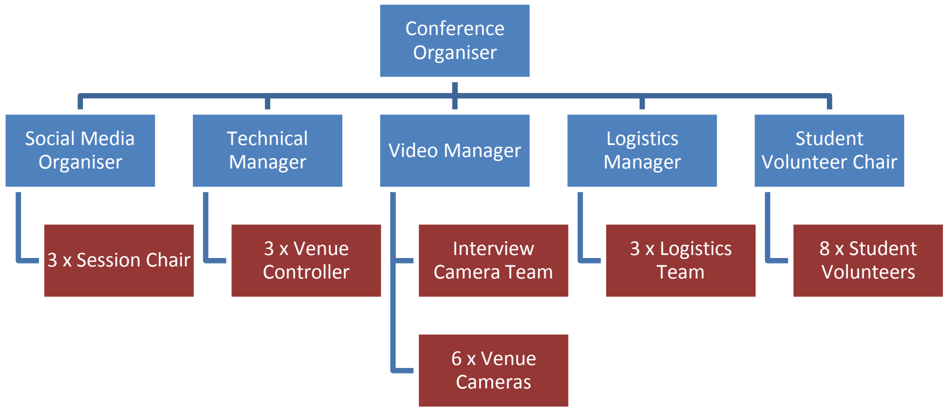



*Figure 49 Conference Staff Hierarchy*

Although these roles were well defined in the initial assessment and planning of the event, in practice, during the deployment team members were allocated multiple roles (of similar types) across the duration of the event. Staff based within a session venue (red in Figure 49) arranged between themselves so that they could be in sessions that were personally interesting, and each was allocated a role in half-day chunks (4 hours). During the week before the first event, informal training sessions were held with production crew to introduce them to the tools and processes that they would be expected to use during the event. This introduction included training in existing production technology, such as video cameras and sound equipment, that they would be expected to operate alongside specific ProductionCrate tools. This session simply introduced hybrid-attendees to the technology they would be using, the expectations of their role and the procedure to follow in event of problems, and each crew member was given a one-page document explaining their role within the team and the tasks they were expected to perform. On-the-job training was given by more experienced members of the team (and those who were engaged in the development of ProductionCrate) during early stages of the event through one-to-one tuition and remote support via the radio communication network. ProductionCrate technologies were not introduced at this stage, but were deployed and introduced to the team by a member of the crew who had been allocated a specific ProductionCrate technology. These expert users had received prior training of the ProductionCrate technology through hands-on experience in a lab setting.

### Analysis Approach

Due to the large scale of the two conference events, many of the researchers at Newcastle University who would have been able to provide observational and ethnographic expertise were engaged in conference-related activities (including being ProductionCrate team members). Consequently, a limited and targeted data collection approach was adopted so that I could effectively use the small number of researchers who were available to observe when not performing other roles. During the event, an off-duty member of the ProductionCrate team was assigned to document the use of ProductionCrate equipment in-situ by placing fixed video cameras around key areas of work, such as the Rapid Editing units. In total, eight videos of specific production tasks were collected, alongside five hours of observational video and notes across the event. During these times of observation, they were instructed not to intervene in the observed crews' workflow. This is analogous to the observation approach used during the StoryCrate deployment, in which acts of self-reflection by the crew during the event would have increased cognitive and temporal pressures for them which would have taken away from the natural characteristics of in-the-wild deployment. Augmenting this observational data was a list of key 'vignette indicators', specific situations observed by the research team that would yield valuable analysis. These were recorded in journal form by lead members of the production team. These notes were then used as recall prompts during later interviews. Post-event, individual interviews were conducted with a cross-section of the crew, aimed at gaining insight into their experience of performing the role of a 'hybrid-attendee' and the effect that

ProductionCrate had on this experience. Ten guided interviews of approximately fifteen minutes each were conducted with a range of the crew. These interviews were transcribed and used as evidence for analysis. Anecdotal evidence of collaborative successes and failures was collected during these interviews. Questions were focussed on drawing out the crew member's perception of their role within the production team. Finally, a group interview was conducted with the three organising members of the production team, using vignettes from previous individual interviews and a timetable walkthrough as prompts for an open discussion. The rapid ethnography approach used for gathering data during the StoryCrate deployment would also be appropriate to the in-the-wild ProductionCrate deployment. Unfortunately, this approach does not take into account the fact that the hybrid-attendees were 'researcher participants' (Johnson & Rogers, 2012), and due the unforeseen lack of available staff members to perform these ethnographic roles, there were very few opportunities for observation. Instead, to generate a richer understanding of how ProductionCrate was used during the event, I targeted ten 'key informants' across all of the designated production roles with limited video documentation during the event and interviews afterwards. A thematic analysis (Braun & Clarke, 2006) was then performed on the interview transcripts, which identified four key themes. I describe these themes below via vignettes from the hybrid-delegates.

### *7.2.2 Initial Analysis*

My analysis is focussed on the performance of ProductionCrate as a suite of tools to support the production of a media-centred academic conference event, and in particular the appropriate use of ProductionCrate tools by the 'hybrid-attendee' crew that were selected to perform as the production team. Specifically, my interviews and observations were designed to draw out in detail the crew's perception of ProductionCrate as a supportive tool, and their experiences as part of a situated team performing production roles. Four key themes emerged from my analysis of the ProductionCrate deployment at the DIS and Pervasive conferences. Using quotes and vignettes from the deployment to illustrate my discussion, I have presented my analysis in four distinct themes.

### The Production Feedback Loop

The individual production feedback loop was a key measure of success for the design of ProductionCrate most specifically to maintain a set of recent content available to the Director. The design of the Rapid Editing unit constituted a trade-off between quality of clips (and the expectation of quality by the operator) and speed of editing. When discussing this editing process, one of the camera operators comments:

> *"With that quick turnaround I would be equally worried about quality in terms of editing down the clip… but it was good being able to see that quick feedback." - Interview Camera Operator*

Although the Rapid Video Editor limited his ability to fine-tune an edit, particularly in setting the in and out points, the benefits of a fast feedback cycle from ingest to editing quickly became apparent as he became more familiar with the interface. The benefit of this feedback was further supported by the ability to see the results of their work in and around the conference venue soon after completing it:

> *"Realizing after the first session how we needed to find quieter [and] better lit areas. What you see on the monitor comes out differently on other screens. That was a big help." – Interview Cameraman*

By providing such a rapid turnaround from capture to broadcast, the team altered their practice in response to viewing their content, continually updating their workflows as the event progressed. These iterations of their practice improved their skill in operating the technology and their production decisions relating to content . The immediacy of feedback reassured the crew that footage was good quality, giving them ownership over their content and boosting confidence in their own skills. However, footage unexpectedly needed transcoding from the cameras in order to use the edit system, so this theoretically fast workflow was significantly extended in time due to an unexpected workflow step:

> *"Once it got to the edit box in the right format it was really, really quick" – Camera Operator*

> *"Without that conversion, I reckon everything would have been 80-90% faster…that would have been an hour a day's work, as opposed to 5-6" – Video Team Leader*

These problems significantly extended the time between starting the edit process and deploying finished clips into the system, breaking the temporal understanding the crew had of the content and the feedback loop between production and consumption:

> *"… it took a couple of hours, by which time I sort of felt with some of [the content] that it wasn't quite relevant." – Video Team Leader*

These problems led the crew to redefine their role as providing *"a running documentary of how the conference was going, rather than how the conference is going now"* (Camera Operator). They did this by accumulating video clips into a wider piece of content over the extended duration of the event, therefore becoming 'documenters' of the event rather than 'news-reporters' as envisaged. In their role as attendees, this documentation style of media capture impacted on their perception of a rapid content feedback loop, as most content did not get broadcast on displays until much later in the event, and clips lost the context of any related temporal events.

### A Directed Narrative

By allowing social media vetting to take place from anywhere within the venue via a wireless tablet, a Content Curator could gain multiple perspectives of the event by moving location (and performing other roles) while managing conference content. In one instance, the tablet holder was outside the event venue vetting Tweets during a presentation session, and comments:

> *"There were points when I went back… I took the tablet with me and sat it by my desk and kept doing the tweets. It wasn't really the same." – Content Curator*

In the context of their role, the Content Curator is describing how being situated within the event space affected their understanding of the event. This reveals that being situated within the venue for this task was useful for gaining context and appreciating the nuance of responsive social messages. This was especially apparent in scenarios where reflexive judgment was required, such as when offensive content was submitted:

> *"A lot of tweets with expletives, which were actually quotes from the keynote speaker. … I thought that actually there is a context issue there…it's a fleeting moment, when it scrolls across a screen…that's a completely different thing. That's the judgment call that I took." – Content Curator*

Being present in the venue provided a context and timely understanding to Tweets that was gained from listening to the presentation that the media related to. The Curator was aware of the whole context of the presenter's quotes and was therefore better informed to judge the offence of truncated quotes from Twitter. By only including Tweets in the media output that were specifically selected for their content, the Content Curator could choose to include social media that inspired particular lines of discussion. Through experience, they built up a reactive workflow and their own editorial rule-set for choosing which Tweets to include in response to emerging discussion topics. The ability to view entire Twitter conversations on the tablet helped in the task of selecting more valuable Tweets from the many being submitted, only choosing appropriate lines of discussion (e.g. not displaying 'note taking' style Tweets:

> *"…I ended up only vetting things that made a new point, rather than repeating what the speaker had said, unless it was a really key point." - Content Vetter*

The Content Curators' emerging rule-set included the decision not to display Tweets primarily formed of URLs or links to images, considering these *"pointless"* on the scrolling displays. All of these decisions involved understanding the content and context of a message, as well as the context of its use (and future use) within the wider event. Similarly, the Video Team Leader comments that, because the Rapid Video Editor did not display clips from previous editing sessions, they lost the context of their edits within the wider event narrative:

> *"I think the way the edit box was set up though and the fact you can't see the whole set of clips, the montage that's going out, I couldn't really feel how that was going" – Video Team Leader*

This situation arose because the edit box was designed to focus the editor on the specific task, but my design presumptions resulted in editors losing context amongst the event narrative:

> *"What would have helped even more was some sort of indication on the edit box, the actual shape of what we were producing." - Video Team Leader*

Whilst designing the Rapid Video Editor to reduce cognitive load for the user, this resulted in an interface that limited access to previously recorded footage. Unfortunately this prevented users from comparing current footage with previous footage as they could not retrieve any footage already available within ProductionCrate to compare and contrast current edits against to gain an understanding of the media already available, and what would be relevant to edit. This content was only available to Media Director's through the tablet interface, or if content was being broadcast to nearby ambient displays.

### Managing Cognitive Load

Although I designed ProductionCrate tools to simplify functionality and reduce complexity, there were still some instances in which hybrid-attendees had to use standard production equipment such as sound decks and microphones. Their unfamiliarity with this technology resulted in some operators feeling intimidated by the amount of new technology as a whole, without being able to distinguish ProductionCrate technology from the traditional production technology (such as mixing desks):

> *"It was less that it was actually a lot to do, and more that it was quite intimidating. There was lots of kit, lots of flashing lights, lots of buttons. Actually all you had to worry about was three volume sliders." – Venue Controller*

I anticipated that there would a steep learning curve associated with both ProductionCrate tools and the traditional production technology. In allowing staff to frequently switch between attendee and operator roles however, the team did not have enough *continued* use of specific ProductionCrate tools to gain enough experience. Team members who used ProductionCrate tools for a full day became more adept at using the tools over the duration of the event than those with half or quarter day shift patterns. When talking about this changing shift pattern, the Director comments:

> *"…we were dealing with volunteers...people were doing it in half day bursts… it was like this see-saw graph of learning how things worked." – Director*

This account suggests that although able to participate as attendees, the team lacked cohesiveness because team members were consistently moving through this learning phase. In response to this and to reduce the amount of new tasks that operators were to perform, certain tasks were scheduled (which in themselves were not complex but added to the overall complexity of the role) to be performed only once daily e.g. changing microphone batteries:

> *"One of the things we did was have [a volunteer] go round every morning... So we got over the training overhead of that, by having someone else do it" - Venue Controller*

One staff member comments that on comparing their role as an attendee and of a staff member, participating as a staff member took precedence over participating as an attendee:

*"Actually the thing that I ended up dropping was paying attention to the talks, because that was the non-critical thing at that particular moment in time." - Venue Controller*

Another crewmember agrees, commenting that their attendee experience suffered:

*"So I think the information… load was pretty enormous… I'm juggling a few different roles there ... it degraded my conference experience having so many things to do." – Venue Controller*

Additionally, one crew member comments that their cognitive load not only increased by their production role, but also their switching between attendee and production crew:

*"I was always going through this phase of conflict … I was part of the team…I was going to support the team all the time…I was trying to actually learn something," – Support Technician*

Although clear ProductionCrate roles were defined, in some cases these conflicted with the attendee's own expectation of their role in the production, creating a constant tension between the attendee and staff experience for the team member. The result of this tension was a conceptual breach of the hybrid-attendee role. Members of the production team were dropping their ProductionCrate roles in favour of maintaining their engagement with the content as attendees, rather than seek to find a balance between the roles. Although natural, this reaction brings to light the fluid assignment of production roles in such a team, where members of the team can cease to provide useful input without central control. To decrease the amount of new technology to learn, rather than implementing a complex system of digital communication between staff members, an in-ear analogue broadcast radio system was deployed. A crew member comments on the reassurance this provided in relation to being part of a wider team skill-set:

*"The fact they all had radios, and they knew even if they didn't need them, they knew there was somebody just outside the door who did know how to work it. This was enough to get rid of the panic." - Venue Controller*

In addition to providing a method of direct communication for troubleshooting, radios proved effective in keeping disparate staff peripherally aware of the event as a whole, without monitoring a specific piece of technology:

*“I always knew when there was a panic in another room, because you got it through your mic, but that was not always useful … you start to feel anxious for them, but there is nothing you can do.” - Video Team Leader*

Unexpectedly, the social media feeds associated with the event also facilitated this awareness between venues. At one point a technical problem in a nearby venue was picked up by this team member: *“You could see tweets from other sessions…so I was really aware of it because of the twitter feed”* (Camera Operator). In this example, while the staff member was consuming Twitter content as an attendee, particular content triggered them into their hybrid-attendee role, peripherally moving them into a state of awareness about other members of the team. This transition was accomplished without any direct interaction with ProductionCrate, and without their having direct responsibility for the production problem that was occurring.

### Unexpected Workflows

The nature of in-the-wild deployments meant we were powerless to shape every aspect of the attendee media experience and the engagement opportunities that existed. At one point during the event, an offensive Tweet accidentally became vetted and displayed in a presentation session. In reference to this incident, the production team member performing the Director role at that time comments:

*“One thing that’s coming out of this is that the whole idea of it being curated is not … necessary, from the delegate’s point of view. It was the fact that it was easily interpreted that these have obviously been vetted, that was why there was some offence registered.” – Director*

Here the Director suggests that positive vetting may not be needed, highlighting that it is not always easy to direct the conference narrative as expected. In this case, Twitter users are used to interpreting what they read in relation to the rest of Twitter, so in an obviously controlled media stream, it becomes more apparent that someone is making an active decision to display it and the implication is made that content is not truly responsive to the situation. In this scenario, the re-purposing of Twitter as a public display output, shared by the multiple attendees means that things people might have ignored in their own personal feed (of the event) is treated differently. The perception of someone’s control over the Twitter output through the vetting process turns the display output into an ‘official’ mediated content stream and gives creditability to the content.

A further implication for in-the-wild research is that the production feedback loop I designed to support in the production workflow can also be seen in the prototype development during the event. This style of incremental updates is often described as an 'Agile Development' process but rarely does it happen during a live deployment such as with ProductionCrate. In one case, features were incrementally added to the Web Relations Manager allowing updating of content at the end of the day. This was in direct response to the fact that the main tasks for Student Volunteers—microphone handling and question entering—occurred simultaneously:

> *"… the one thing that we wanted to capture was the thing that was hardest to capture…In the end I was typing with one had on my phone whilst running around with the microphone." – Student Volunteer*

Adapting to this, the crew recorded questions in note form (on either paper or electronic devices), subsequently batch entering them into the app after the event:

> *"Most of us were inputting everything at the end of the day. We needed to have the ability to input the data retrospectively." - Student Volunteer*

### *7.2.3 Lessons from the Newcastle Deployment*

The initial deployment of ProductionCrate in Newcastle yields many interesting insights that would have been unlikely to have come to light with the demands and pressures associated with real-world event production. Although in general the media production of the two events was considered a success, not all of the individual elements of ProductionCrate's ecosystem of media were utilized in the manner and to the extent anticipated in their design. Some issues can be directly attributed to the features of an unpredictable event and my under-estimate of the high demands that both running the event and operating the system placed on the non-technical staff. The significant human resource required to deploy the technology also had a consequence for the level of empirical evidence that could be collected; consequently, the observational and subjective data relating to ProductionCrate "in action" lacked depth and detail. In hindsight, the team struggled to apply resources to gathering research-related data because of the many roles each staff member was performing. Producing a high quality event became their main priority, rather than collecting research data. The situational factors that impacted the conference event and the production inherently impacted on the research team and their ability to perform alongside their other roles. The unforeseen issues encountered can be classified into three categories:

- **Technical**: Various forms of technical failure were experienced, related to venue infrastructure, unforeseen volumes of traffic and under-tested technology. Some of these issues were located and fixed during the deployment, with overnight implementation fixes or infrastructure upgrades. Other issues related to particular variants of camera technology being used that caused equipment-specific issues in the workflow, and which could not have been tested before the event due to lack of access to test these devices.
- **Workflow**: Although carefully planned, the amount of time needed to perform some production tasks was not anticipated. This led to some members of the team having no pending tasks for long periods of time, and then subsequently having multiple technologies and roles to fulfil simultaneously. In these situations, some ProductionCrate technologies were under-utilized to give time to those deemed more important for maintaining the overall attendee experience.
- **Social**: Even in situations where ProductionCrate technologies were operating satisfactorily, a number of social elements prevented the team from fully making use of the technology to drive the attendee experience. Foremost of these issues was the reluctance of attendees to be interviewed for any reason, weary of what the footage may be used for. This issue individually could have been negated through better preparation and advertising of the system prior to the event. Given this lack of awareness, attendees were not aware of where content was being distributed within the venue.

To address a number of these issues and to better evaluate aspects of ProductionCrate, key elements of the system were redeployed at further event. This provided the opportunity not only to address certain technical shortcomings that came to light during the initial deployment, but to evaluate the effect that simultaneously organising the event and using ProductionCrate has on the overall workflow by separating the inherent pressures of event organisation from the media based workflow associated with ProductionCrate. By re-deploying a subset of the ProductionCrate platform in another event, my efforts were concentrated on key production workflow aspects which were not fully evaluated in the first event. For this next event, I refined the use case such that the production team were not part of the conference organisation team. This team would attend the event as normal attendees, providing an additional attendee media experience through ProductionCrate during the event. Although not in line with the original use case in which the host institution staff performed all production roles, this evolved use case does take into account organisational and financial pressures of the host institution. A production team was to be deployed as a non-professional team of researchers (no cost to the host) at an event in their field, but not an event they helped to organise.

## 7.3 Aberdeen Deployment

In early October 2012, a subset of the ProductionCrate media elements was deployed at the EPSRC Digital Economy Hub academic conference event in Aberdeen, UK. The event consisted of three days of session presentations, two social events and an exhibition, with around 250 attendees; as such, this was a very similar format to the main conference phase of the first ProductionCrate deployment. In contrast to the first deployment however, in this event we would not participate in the event management and logistics organisation, instead working as hybrid-attendees to provide a media production service for the event, making use of interested attendees from my institution as a hybrid-attendee production team.

Given the issues highlighted from the Newcastle deployment, three primary goals for future deployments were:

- to realise a rapid editing workflow (<1 hour from filming to consumption).
- to fully evaluate RedTag and the effect on the editing workflow
- to engage attendees with social media content through rapid response to new content.

These objectives allowed for a technically and logistically smaller deployment, whilst preserving technical and workflow elements that would be of value to the study.

### *7.3.1 Follow Up Deployment*

The event was located in a dedicated conference facility in Aberdeen, 350 miles away from the initial deployment site in Newcastle. This necessitated the transport of all of the hardware and infrastructure associated with ProductionCrate, and installation in an unknown venue. Six members of research staff from Newcastle University travelled to Aberdeen to install and operate ProductionCrate for the event, and each member of the team was a researcher in the same field as the conference event. Half of the crew had prior experience operating elements of ProductionCrate. The sub-set of ProductionCrate technology redeployed at this event consisted of:

- ProductionCrate Server and Data Store
- 180 RedTag badge attendee transmitters and 6 camera mounted receivers.
- 5 channel video streaming system.
- 1 Rapid Editing unit.
- 2 Mix Controller tablet PCs

The deployment of this technology enabled the production team to support the following attendee-facing technologies across the Aberdeen venue:

- 3 TV channel displays.
- 3 displays situated outside session venues.
- 3 Talk Timers.
- 3 LED displays inside session venues.
- 2 interactive programme tables.

The team in this second deployment would fulfil similar roles within a production hierarchy to that of the Newcastle team, although reduced in numbers. The student volunteer role was removed (as the event did not have any student volunteers).

### *7.3.2 Re-Deployment Improvements*

The limited lead-time before the Aberdeen deployment meant only minor changes to ProductionCrate tools could be realised. Technology that was highlighted in my initial analysis as central to the production workflow was part of a short design iteration before the Aberdeen deployment. In particular, those technologies that presented significant challenges or hindrances to the team were redesigned. I categorised these iterative changes into three areas in response to the feedback and analysis gained from the Newcastle deployment.

**Infrastructure**: To re-deploy ProductionCrate to a new venue outside of the infrastructure on which it was initially developed, it needed to be able to operate in a stand-alone environment, a true ‘in-the-wild’ scenario, without the support of my institution systems such as an existing networking infrastructure, reliable upstream internet connection and predictable wireless Ethernet access that the system was initially developed within. This involved consolidating server services into a single rack-based hardware unit, which would be self-sufficient when transported and installed in a new location. Each ProductionCrate system would need to quickly discover this new server on a new network in the new location, and auto-configure to the new network requirements. In the new location I could not guarantee a fast upstream internet connection, and so ProductionCrate needed to be able to respond appropriately to connection outages and slow connections at the new location. The Newcastle deployment experienced connection overloading on the ProductionCrate database server, caused by large amounts of data being repeatedly requested by many devices simultaneously. During the Newcastle deployment, I responded to this by moving the database server off-site to a managed hosting company, but in Aberdeen I had no guarantee of a reliable up-stream internet connection to employ this option. Instead, the database server was separated from the main ProductionCrate server into another server machine in the portable ProductionCrate rack. Fixes for bugs revealed by the production crew during the Newcastle deployment were applied across many of the ProductionCrate devices, for example the ability to change the vetting decision was fixed in the Mix Controller, and Talk Timers effectively responding to intermittent network connections.

**Workflow:** The primary focus for the Aberdeen workflow was to decrease the time between social media posting and routing the message to a display for attendees. In the first deployment this could range from thirty seconds to fifteen minutes, which dislocated the timing of the Tweet and the event to which it was referring, meaning much content displayed within venues was unrelated to current events. Due to ProductionCrate’s distributed network of independent devices, four content polling steps are found in the content system. For Aberdeen, the polling rate at each stage was reduced so that the maximum polling time across the workflow was set at three minutes. In the Mix Controller software, polling for social media data was separated into a faster polling sequence from the rest of the content, to avoid backlogs in UI updating in order to provide a faster response to crew members when responding to

Tweets. Social messages were not only routed too late to LED displays, but also remained on the display for long periods of time, losing their temporal context in the presentation session. Messages were constantly scrolling on the displays, which allowed attendees to become accustomed to content and desensitised to content updates. To combat this, the LED display driver was updated with a timeout feature that displayed a message for just five minutes before removing it from the display. Messages would 'fall' off the screen and leave it blank until a new message arrived. The RedTag system was tested thoroughly before the first deployment, but in practice multiple factors prevented it from being useful to the editing workflow. Each stage in the RedTag workflow was re-tested and bugs removed during the Aberdeen re-fit: camera-capture, signal processing and editing. After examining the workflow, it was clear the receiver hardware was experiencing difficulties after entering a pre-charge state, and this issue was fixed by re-programming all receiver devices.

**Social Media**: Although many of the updates to ProductionCrate were technical in nature, a number of elements of the team workflow relating to generated content were reconsidered for the second deployment. I abandoned both the interview and question entering web applications for the second deployment, due to a lack of staff available to attend presentation sessions (and thus be contextually aware of the content in each session). In the Newcastle deployment I was  uncertain if attendee intervention with their RedTag transmitters was the cause of missing data (such as removing badges for presentations), and as such multiple RedTag transmitter combinations and scenarios were tested in a lab setting before travelling to Aberdeen. Unfortunately the badge-holders at the Aberdeen event were able to rotate allowing the possibility of hiding the RedTag transmitter and I was unsure how this would affect both accidental privacy and active hiding of badges.

### *7.3.3 Evidence*

Rather than engage additional researchers as observers for the Aberdeen deployment, and with an awareness of the complexities in capturing data from the team highlighted in the Newcastle deployment, all six crew members in Aberdeen were asked to fill in a personal log book of their experiences both in the morning and after the event in the evenings. This log book provided prompt questions to elicit a range of information and personal feedback on both their experience of working with ProductionCrate technologies and their response to using them within the context of the event. These logs were evaluated using thematic analysis to find common events specifically related to ProductionCrate during the deployment. The themes that arose were then presented in a group interview with the crew a few weeks after the event as probes to trigger discussion around key events in the production.

### *7.3.4 Results and Analysis*

I centred my analysis efforts on the experience of the hybrid-attendee production crew and the tools that I built to support them. Throughout this analysis however, an awareness is retained of the production output which was created by these tools and how this impacted upon the attendee experience of the event. Three key themes arose from the thematic analysis of the log books and subsequent interviews: *supporting production processes, the production experience and supporting production values.*

#### Supporting Production Processes

*Interaction and Content Seeding:* From the first deployment it was noted that 'seeding' social media streams with content encouraged attendees to engage with content, but that the level of engagement varied dramatically between presentation sessions and other times during the conference. In this second deployment, social media feeds were not utilized particularly frequently (possibly due to the type of attendee and topic interest). The crew attempted to seed content into the Twitter feed to build up interest for other attendees:

> *"Tweet more myself and mention tweet screens in tweets to draw people into the dialog." – Mix Controller Operator*[47]

Unexpectedly, the crew were seen interacting with both the Touch-Tables and Tablet interfaces in public areas, 'seeding' interaction with these devices. This intrigued and encouraged attendees to engage. Incidentally, the Rapid Video Editor was placed within the same attendee space used for break-time networking at the event. Attendees became interested in the ProductionCrate equipment being operated and maintained, and engaged with the crew in discussion of these. Conversational scenarios such as the following ensued:

[47] Quotes used are from log-book entries

*“When editing, often people would approach and ask about what I was doing. I would explain and often get into conversations about other things.” - Rapid Editor Operator*

*“…I was asked to explain it to a few people, this happened when smart tables needed rebooting.” – Crew Member*[48]

Explaining to attendees how the ProductionCrate technology worked supported the crew in understanding their workflow and the equipment, whilst encouraging attendees to submit content of their own. The crew discussed their production roles during attendee networking opportunities, often demonstrating the capability of the Tablet Controller and Rapid Video Editor as explanations of their presence at the event. Post-event analysis revealed that rather than seeding content directly (since the crew did not have a contextual understanding of most of the presentation session content), they were seeding ‘meta-content’, Tweeting messages that highlighted ProductionCrate technology and opportunities for attendees to contribute, with the aim of driving social media uptake.

*Situated Production and Performance:* ProductionCrate’s mobile interfaces allowed production crew to immerse themselves in the event as an attendee to experience content. The distribution of the team physically across the venue supported the emergence of specific strategies for routing and vetting content, as highlighted by one crew member:

*“[I used the] tweet interface both in the conference sessions in which I tended to choose talk specific tweets, and out of sessions where I chose a distribution of tweeters.” – Mix Controller Operator*

A by-product of being located throughout the event space was that the production team was visible to participants at the event, often mingling amongst typical attendees at break times and during sessions. This awareness encouraged a sense of performance amongst the production team, who began to envisage themselves as performers rather than ‘backstage’ technicians. One crew member comments:

*“Yesterday was all about preparing, today is about performing. So I think the whole day will be different...” – Crew Member*

[48] A member of the ProductionCrate hybrid-attendee crew

*Editing Footage:* The majority of the content available to the Director consisted of video clips produced by the crew during the event, meaning the primary production task required was operating cameras and the Rapid Video Editor to produce short succinct clips from session and interview footage. Although the turnaround time from capture to editing was significantly reduced in comparison to the Newcastle deployment (due to bug-fixes and compatible camera hardware), the crew still lacked the editing precision needed to effectively edit shorter interview style clips, commenting:

> *"[You] need a preview of video on the in and out points to allow precision pointing following up from picking a region to edit with Panopticon." – Camera Operator*

The raises a fundamental dichotomy in the expected types of editing that need to be supported by the Rapid Video Editor: i) editing long presentation footage from a fixed camera from clips up to twenty minutes long, and ii) editing short diverse clips from a roaming camera, often as little as twenty seconds in length. The former requires little precision in editing to gain production value, whilst the latter requires accurate positioning of the clip points to produce valuable content, a process that the crew struggled with:

> *"Video editing was sometimes a bit unstable, hard to position end point." – Camera Operator*

In addition to more precise clipping, crew also suggest providing a list of clips that have been edited to provide context in line with the requests from the Newcastle production team.

### The Production Experience

*Participating as an Attendee:* The production team used their own experiences of past academic events (as attendees) to guide the production decisions they were making. The understanding of how they would be participating if they were solely attendees helped them to understand the effect of their production choices on non-hybrid-attendee participants. One crew member comments:

> *"[I] played around with the smart tables for a bit but somehow couldn't find the person I was looking for." – Content Producer*

This feedback suggests that envisioning themselves as full attendees (without their production role) helps their understanding of how the media output they are producing is being consumed. To support their understanding of the attendee event media experience, each member of the production crew develops a positive feedback loop , altering the way they perform production tasks in response to how the output is used in the production system. This is analogous to watching a TV show being broadcast as you are mixing it, as would take place in a live broadcast. Through this process, the crew became aware that attendees were not engaging in particular elements of the production such as the TV displays (due to a lack of audio playback). Anecdotal evidence indicates that the crew were using their own consumer experience to guide which parts of the production they focused their effort on to improve production value. Although the evidence suggests that the crew were deliberately engaging in the consumer experience, they fundamentally felt apart from the rest of the attendees:

> *"I didn't feel part of the conference "proper" though, so it wasn't a "normal" conference experience." – Crew Member*

In this deployment, the crew became more engaged the production workflow as they began to enjoy the experience. Post-event, it was highlighted that radio communication added a personal element to the production team and facilitated joking between crew located in venues on their own, as well as providing a critical knowledge feedback channel for technical questions. Observation of the Newcastle deployment demonstrated that inexperienced crew members do not have the skills and experience to properly judge the quality of their outputs, and as such rely on their enjoyment of the content as consumers, and their experience of the production process, as a success measure; this was again highlighted in the feedback from Aberdeen.

In both deployments, the crew were members of the research community running the event. Their agreement to be part of the production team reinforces their commitment to being involved in the event as interested parties (as they received no incentives for their participation). This motivation is distinctly different from other types of event contribution, such as Student Volunteers (who receive financial or accommodation remuneration), or professional event crew (who are paid to perform their role). As such, designing for a crew that is driven by their sense of contribution is a key concern for ProductionCrate. As one crew member comments about real-time feedback of decisions they made:

> *"Also I used the tweet moderation tablet…. This was great fun and I had a nice sense of contributing to the conference feed, especially due to the real-time arrival of tweets." – Tablet Operator*

*Workflow:* Crew members described scenarios in which ProductionCrate tools supported them in creating their own workflows as part of their production role. The event was initiated with team members being given distinct roles and shift times, but during the event the team dynamically reconfigured themselves to meet production demand. For example, Tablet Controllers were being passed around to whomever was free to operate them (even if they were not on shift). As such, personal moderation and routing styles developed for each crew member:

> *"[I] Had to make my own moderation rules in which very frequent tweeters did sometimes get rejected. Was working towards approving a fair amount of positive and negative comments." – Content Curator*

As with most live events, a large amount of time with minimal activity was interspersed with short periods of busy activity. One crew member describes the effect of this workflow on their role:

> *"[The] 'Rush hour' as people were gathering in the main hall made me take up different roles within a short time frame." – Crew Member*

ProductionCrate's modular physical and software construction supported an efficient set-up and teardown process, and allowed systems to be brought online incrementally, a beneficial factor for the crew:

> *"The modular nature of the devices made teardown very quick (relatively). I would imagine that this would make the roll out of these technologies in a non-research environment viable where time / cost is an issue." – Crew Member*

This speed was partly due to the limited number of setup-steps required for each individual tool, but also the ability to incrementally test the ProductionCrate system as it came online during setup. The experience of setting up the equipment then formed the basis of their interaction during the event.

### Supporting Production Values

*Amateur Crew Challenges:* The production crew had a range of skills in, and experience of, production, but all had experience in attending academic conference events. During times without imminent production responsibilities, one crew member comments: “It was easy to get caught up networking and socialising.”

As the ProductionCrate technology was unknown, even to crew with experience in media production technology, ProductionCrate technology failure resulted in crew members falling back into a pattern of attendee participation with the event rather than attempting to solve problems. In such an in-the-wild deployment, where crew were interacting with members of their own research community, they did not perceive themselves as ‘professional’ crew, with the related consequences (such as repeat business if they did well, or a bad reputation if they did not). As such, their lack of skill and frustration in not being able to fix failing equipment, paired with their lack of professional incentive to perform, resulted in a natural fall back to their attendee roles. Interestingly, because ProductionCrate contained many consumer technologies familiar to the crew and simple computer based technologies such as networking and PC install, troubleshooting identifiable problems was possible in some situations. During setup, one crew member comments:

> *“Also [I] got a glimpse of how the technologies are connected and an understanding of the components involved.” – Crew Member*

A key factor which distinguishes professional crew operating efficiently in a production environment is their ability to effectively multi-task during busy periods. Crew members (primarily inexperienced with production of any kind) commented that they are “juggling multiple demands” throughout busy phases. Combined with an expectation of problems to face during setup, experienced members of the crew felt that introducing inexperienced crew would increase setup time. In design terms, this suggests the bar for newcomers to production is still set too high, and from a professional viewpoint some ProductionCrate tools presented too much of a challenge for hybrid-attendees, especially during setup.

*Responsive Production:* The crew dynamically allocated production roles in response to the current production needs, but with such a small team (compared to the Newcastle deployment), responsiveness to radio communication was key. In response to a question on the effect of radios on their workflow, one crew member describes:

> *"Yes, constantly. Things take longer or shorter than expected and radios require responsiveness." – Camera Operator*

This suggests that although the event was approached with a clear plan for separation of tasks and roles within the team, in practice they exhibited flexibility in distributing tasks within the team which reacted to scenarios primarily instigated by radio contact. Further crew comments, *"[My role changed] constantly though the planned workflow was somewhat reactive in any case,"* suggest the crew quickly became aware that their primary role was to be reactive to scenarios during the event within the context of their production roles, either through performing technical tasks or responding to event content. This highlights a key tension in production planning between preparation for a production schedule and preparation for a responsive production. Traditionally, crew at an event would not consider themselves to be engaging with the event content, but in a hybrid-attendee scenario an inherent understanding of the event content can be leveraged by the production team to curate a responsive media experience for the rest of the attendees. By increasing the ratio of responsive content to that of static content crew are exposed to time-based and constantly updated media. The resulting media output containing this dynamic media provides content relevant to current events for attendees, fostering a feeling of 'liveness' for attendees which encourages them to submit further user-generated content via social media channels. Although ProductionCrate enables the production crew to engage more closely with dynamic event media, one crew member discusses their disappointment in their perceived lack of understanding of the event content due to minimal feedback received from attendees:

> *"I think today will allow for a slightly more proactive approach, although user feedback about useful footage has been minimal so I'm not 100% clear what we are looking for." – Interviewer*

This lack of attendee engagement reduced the crew's ability to discern relevant or useful content when curating discussions.

*Feedback and Stakeholders:* Production crew operating outside of presentation sessions (such as the Director) were not obliged to be in a particular venue, and as such it was sometimes difficult for them to associate their own production actions with the attendee consumption experience. One crew member comments:

> *"[It was] hard to know if pushing tweets to the conference halls was appropriate." – Content Curator*

Crew performing interviews could not be present at all presentation sessions so choosing appropriate topics and questions for presenter interviews was more difficult and lacked specific contextual references. Rather than making use of the mobile-interviewer application, in the Newcastle deployment, production crew were using displays situated throughout the venue as feedback for their individual workflows. This was the case in Aberdeen, but the crew felt that they still lacked an overview of the event:

> *"It was hard to get an overview of what still had to be done and how to do it." – Crew Member*

> *"As I did not have an overview of the tasks involved I sought out tasks I could solve on my own." – Crew Member*

> *"Biggest challenge was getting an overview although this was not needed to perform the tasks." – Crew Member*

Due to the lack of audio capability on the TV displays, the feedback loop was not properly completed. Knowing that attendees would not fully appreciate the directed content from the situated displays, the crew were discouraged from generating new content. The setup phase of production was highlighted as requiring a clearer shared representation and state awareness of the team. All ProductionCrate technology was deployed into a 'black-box' (no existing infrastructure), across a large multi-room venue, so at all points crew members were spatially dispersed. Radio communication facilitated the setup process, but crew lacked an in-depth awareness of the state and location of equipment.

## 7.4 Design Considerations

ProductionCrate consists of a specific configuration of technologies that support the production workflows required for multi-media academic conference production. Part of this ecosystem is a set of bespoke production technologies targeted at specific production roles, to be used by a team of hybrid-attendee volunteers during each event. Underlying the individual production tools used by the hybrid-attendee production crew was a networked infrastructure allowing flexible reconfiguration and access to the multiple media streams in the production. The design of these technologies was driven by two distinct but connected considerations. First, I wished to provide a cohesive multi-format media experience making use of multiple types of live, social and static content. Second, I had to account for the hybrid-attendee nature of the production team running the event to produce this output. The deployments and evaluations of the ProductionCrate system at three academic conferences provides us with a rich understanding of the design considerations for this class of technologies and interfaces in the future.

### *7.4.1 Supporting Hybrid-Attendee Production Teams*

Through their involvement in the deployments I noted that hybrid-attendees experienced a different and arguably richer relationship to the conference presentations and papers through their involvement in content production. By introducing attendees as stakeholders in the crafting of media content we can broaden the live event experience for all participants. By supporting attendees in vetting and routing peer content, group discussion can be directed in collaborative and emergent ways, encouraging attendee engagement in the topics of discussion developing at the event. Further supporting this, the use of mobile production tools allowed hybrid-attendees to integrate into the audience of sessions, to perform production roles from the physical and contextual perspective of a normal attendee. These mobile tools supported a flexible workflow, allowing appropriation in multiple ways depending on the user. The mutual awareness between crew and attendees gained by integrating into the attendee space encouraged a sense of performance amongst the production team, who began to envisage themselves as performers rather than 'backstage' technicians. The ProductionCrate tools were used as props to prompt discussion and drive interest in the media output of the event. Underlying the individual production tools used by the hybrid-attendee production crew was a networked infrastructure allowing flexible reconfiguration and access to the multiple media streams in the production. Deploying a peripheral audio communication system benefits team awareness, supporting inexperienced staff, and providing rapid response for technical issues. Social content streams that staff members already monitored as attendees were used to broadcast administration and support information for production crew alongside content, allowing them to monitor production aspects of the event without switching fully into a production role. In future deployments, this could be taken a step further, integrating production messages directly into the attendee content stream, which may endear attendees to staff dealing with technical difficulties, building a relationship of trust rather than of expectation that currently exists.

Although ProductionCrate was developed to support production tasks without significantly increasing the cognitive load of the operators, both the part-time shift pattern and traditional production technology had a noticeable effect on attendees' experience. Allowing staff to move in and out of ProductionCrate roles multiple times over the duration of the event led to staff not gaining as much continued experience of ProductionCrate tools, requiring more on-going support from experienced members of the crew, and lowering the quality of the output media. Even when positioned amongst sound and lighting equipment that they were not expected to operate, their expectation of equipment failure increased due to the large amount of unknown equipment surrounding them.

Introducing a clear and structured training and operation schedule for these staff would help scaffold their learning and production output quickly. Using their own experience of the event, hybrid-attendees were able to drive a directed media production, interpreting their own expectations to constantly improve both the content and the production values of the event. In future events it may be possible to crowd source most event content directly from attendees, but management of this content will still be a professionally skilled role. ProductionCrate demonstrates that with little training, attendees can perform these more specialized tasks, leveraging their participation in the event to enhance the production without a detrimental effect on their personal experience. Having demonstrated that hybrid-attendees experience a different and arguably richer relationship to the content through their involvement in content production, I can consider the experience of the remaining attendees. By re-purposing the notion of a production feedback loop into redesigning the attendee experience, and by introducing attendees as stakeholders in content crafting, we can broaden the live event experience for all participants. Encouraging attendees to vet and route peer content, group discussion can be directed in collaborative and emergent ways, encouraging attendee engagement in the event topic.

By designing self-contained tools to facilitate each role in the production workflow, the requirement for a constant system of awareness was also reduced. This had trade-offs however, as users lost contextual awareness of the content within the wider media stream due to their limited access to other content and role tasks. Alongside the bespoke technology, providing a peripheral audio communication system benefitted a limited sense of team awareness. It provided support to inexperienced staff and rapid response for technical issues, especially when distributing tasks across multiple venues. In future work it would be beneficial to make further use of the content streams that team members already monitor as attendees (such as Twitter) to broadcast administration and support information alongside content, allowing an easier trajectory between attendee and production roles. For future deployments, this could be taken a step further, integrating production messages directly into the attendee content stream, which may endear attendees to production staff dealing with technical difficulties, building a relationship of trust and understanding rather than of quality expectation that currently exists. Explaining to attendees how the ProductionCrate technology worked supported the crew in understanding their workflow and the equipment whilst encouraging attendees to submit content of their own. The crew discussed their production roles during attendee networking opportunities, often demonstrating the capability of the Tablet Controller and Rapid Video Editor as explanations of their presence at the event. Post-event analysis revealed that rather than seeding content directly (since the crew did not have a contextual understanding of most of the presentation session content), they were seeding 'meta-content', Tweeting messages that highlighted ProductionCrate technology and opportunities for attendees to contribute with the aim of driving social media uptake.

### *7.4.2 Scaffolding Media Direction*

Being mobile clearly supported the fulfilment of the Director role, and allowed the Director to experience the event as an attendee situated in a specific venue. Conversely, by situating themselves in a particular venue, they were limited to understanding the content in that specific room, reducing their awareness of events occurring in other venues. Some Directors sought to combat this by removing themselves from any venue, preferring to stay in the foyer area, but this approach limited their understanding of the content even further as they were not participating in any presentation sessions at all. A particular feature of the Tablet Controller which simplified the Director role was the ability to setup automatic playlists of content, such as 'the last 10 tweets in this room'. This allowed the director to engage as an attendee without constant monitoring and interaction with the media routing system, updating and maintaining when appropriate in response to particular contextual triggers. Throughout the deployments it was clear that the tablet interface could have been implemented as a HTML5 interface similar to the other mobile applications, and thus any device (such as personal mobiles) could have been used. This would have avoided loss of media routing control because of failed batteries on the mobile tablets, or through the tablet being held by another member of the team when it was needed.

### *7.4.3 Reducing Cognitive Load*

ProductionCrate demonstrated that by clearly defining and aggregating production tasks needed to facilitate dynamic content into key roles, production workflows can be compartmentalized and targeted at particular groups of hybrid-attendees who will perform these production tasks. In particular, the distribution of the production workflow across a range of bespoke tools, each tailored to a production role, limited the amount of new technology hybrid-attendees were faced with. Conversely, although ProductionCrate tools were developed to reduce the additional cognitive load of hybrid-attendees through simplification, the requirement of hybrid-attendees to move in and out of their production roles repeatedly throughout the event reduced the effectiveness of this approach, as each member of the team had to spend time re-aligning themselves with the production workflow. This presents an opportunity for designing fewer, more flexible production tools that can be appropriated in response to current production tasks.

Although it was easy to use and could be deployed across any device, the web relations manager was not an appropriate response to the situational factors present in the environment it was used. Users had other production tasks that took precedence over maintaining production data in the same time frame, such as technical support and sound engineering roles. Most users developed their own workflows in response to this, such as writing questions down on paper and entering them after the session had concluded. Unfortunately, the key element of responsive feedback to both the presenter and the Director for routing and interview preparation was lost. As such, these users did not receive feedback on how the data they entered was being used, and quickly withdrew their personal stake in the production process. Crew are clearly driven by their desire to contribute content, and this could be used as a further incentive to produce better quality content during the event. By leveraging their perceived reputation amongst the community of interest, as a known contributor, a rating or scoring system could be used to encourage continued participation by the hybrid-attendees. Subsequently the team may produce content more regularly, which would drive the need for continued maintenance.

### *7.4.4 Supporting Individual Feedback Loops*

The design of a rapid feedback loop within each self-contained workflow tool supported non-professional users performing production tasks by providing them with direct feedback for their actions. This was accomplished both through the design of self-contained interfaces and the utilisation of situated or mobile tools used within view of media output devices such as screens. In turn, this supported self-reflection and critical thinking about their own practice, and a drive to improve. A real-time awareness of how their content was being used was critical to drive this process, in which crew took ownership over content within the event through the knowledge of their effect on the output stream. Most importantly, their personal relation to the content as members of the community at the event drove them to make contextually relevant content decisions that might have been ignored by a professional crew. This personal relationship with the content is only achieved through the use of hybrid-attendees, and can be leveraged to make content selection and routing decisions that would not be possible in real-time from professionals who were not stakeholders in the event (as they would be receiving feedback through social media or other sources). In some situations however, the crew found that they lacked access to previously edited content to build a contextual understanding of the media narrative when performing production tasks. This was in part due to the reductionist approach I took in designing each workflow where only directly relevant content was available for the current task. This revealed a trade-off between reducing the amount of information and content provided to the crew during each task, and the benefit of viewing previous content to contextualize the current process. In turn, this suggests that production technology need not be so severely simplified, and should include the ability to manipulate content in richer ways such as the complex editing features provided by professional tools. Most importantly, the production crew would gain further contextual understanding of available media through access to a wider array of content while performing each production task.

## 7.5 Conclusion

I have presented a prototype media production system that supports hybrid-attendees to produce and deliver high-quality content at academic conferences. The system's design responded to the potential for these non-professionals to be overwhelmed by potentially complex systems. Furthermore, to make the use of the system even simpler, I limited device usage to specific tasks and phases of the production flow. In live use however, it was clear that the hybrid-attendees were far more flexible and responsive to the demands of the event than expected. Furthermore, rather than being a barrier to producing professional content, that they were also members of the events community supported reflections and critical stances on the work they produced. Using their own experience of the event, hybrid-attendees were able to drive a directed media production, interpreting their own expectations to constantly improve both the content and the production values of the event. In future events it may be possible to crowd-source most event content directly from attendees, but management of this content will still be a professionally skilled role. ProductionCrate demonstrates that with little training, attendees can perform these more specialized tasks, leveraging their participation in the event to enhance the production.

# Chapter 8. Conclusion

## 8.1 Introduction

At the core of this thesis are the design and evaluation of two deployments of collaborative technology for situated media production teams. Both the StoryCrate and ProductionCrate systems demonstrated how technology can be designed to support teams in complex environments. The factors present in these two scenarios are also found in the example scenario of a faith based live event introduced in Chapter 1. Key considerations such as supporting random access to media, non-linear team practices and designing technology that supports non-professionals working with professional quality media are found in this domain. To understand the design challenges presented by such complex scenarios, I discussed in detail the situational challenges associated with such tasks and teams, and highlighted the previous work and technologies that could be brought the bear in response. I performed a qualitative analysis of data gathered during in-the-wild deployments of each system, and based on these discuss the impact of each design and the associated technology on the production workflow.

In line with the action research approach that I introduced in Chapter 1 the following discussion considers the impact relevant situational factors in each of the domains for which I design, deployed and evaluated the systems. I highlight features of my designs for TV and conference production that responded to those factors, revealing a set of interaction design elements, concepts and related technologies that are of wider benefit for situated collaborative media production. My aim in both case studies was to improve the existing collaborative production workflow, but for each, the criteria by which improvement could be judged were different. Two of my research questions (first introduced on page 19) had a major bearing on the design to the independent case studies:

*Q1. "How can team based creativity be driven by interactive technology in situated media production environments?"*

*Q2. "How can heterogeneous teams be supported by collaborative technology to provide a production workflow for multi-media COI events?"*

Through discussing the impact of the situational factors that characterise these particular collaborative media production scenarios, my response to my third research question can be addressed in terms of lessons learned that transcended the individual contexts and apply to both media production teams (and hopefully teams with similar pressures):

*Q3. "How can we design collaborative interaction for situated media production and the situational factors that impact on these contexts?"*

Keeping in mind the situational factors I identified in Chapter 1 – Team Members, Professional Considerations, Technology, Liveness, Coordination and Environment – I can compare and contrast specific design choices in relation to these factors and reflect on their impact on the team in relation to both the heterogeneity of the team membership (Q1) and a team's scope for creative endeavour (Q2).

## 8.2 Driving Team Based Creativity

*"How can team based creativity be driven by interactive technology in situated media production environments?"*

StoryCrate was developed to promote the engagement of professional production team members with the content they were producing with the aim of driving creativity within their existing workflow. Many of the design choices made when developing StoryCrate drew on existing understandings of interaction design and CSCW, and some were developed specifically for situational factors impacting on TV production. In this section, I highlight three areas of StoryCrate's design that clearly engaged users in acts of actionable creative practice.

### *8.2.1 Shared Reference*

StoryCrate's state representation used a pictorial storyboard of the current scene. Although this represented information about the current shoot in an easily assessable form, the two actions that StoryCrate was most used for were *playback* and *comparison of two clips*. By enforcing a linear representation of the timeline, the ease with which users could randomly access content was limited, thereby requiring them to undertake a linear search for content (which was not in the same order that it was shot). The constraints of a TV shoot required that StoryCrate be placed in a particular location and left there (due to cabling requirement of the cameras). This allowed many of the crew to be able to see the displays on StoryCrate, but not to interact with it. Additionally, due to problems with sight lines, the crew were so busy performing their normal roles that many of them did not get chance to access StoryCrate until break times. With the assumption that a reference tool does not have to be democratically operated from a central location, it might have been possible to split the playback functions of StoryCrate have smaller personal hand-held devices carried by crew and editing and meta-data roles performed on the main device. In conclusion, a shared reference of the shoot proved effective in engaging particular crew-members with the content in a way that was not possible before. My expectations of more democratic use on the other hand were not met as, apart from the Runner, the traditional shoot hierarchy was maintained.

### *8.2.2 Interaction Modality*

The use of physical tools for interacting with StoryCrate was a specific design decision that responded to two key observation: (i) the importance of (verbal) communication between crew members; and (ii) the practical issues surrounding film shoots whereby crew already carry lots of equipment. In the design of StoryCrate, I demonstrated that tangible tools that embody features and limitations of their associated software function allow the crew to learn tools quicker, whilst avoiding the additional cognitive load of interface elements such as touch-based menu systems. The use of a tangible control with embedded navigation controls allowed for sub-tool control of functions such as list browsing, without the need to implement touch throughout the entire system. The use of pen-based input was particularly successful, especially from the crew's perspective, as it allowed expressive but simple input into what was interpreted as a 'closed' system (i.e. only a single input from the camera). In addition, limiting the number of tangibles allowed social constructs to develop around tools availability and supported communication of actions between users. This was most clearly demonstrated by the case where the Director held onto one of the controls to avoid the Runner moving his place on the timeline. Physical manipulators (tangibles) were key to enabling explicit communication of action between team members. These tools are analogous to the tools currently used by production crew in such situated media production teams, and are based around familiar physical interfaces – buttons, levers and sliders – and where therefore easily assimilated into the production team's current practices.

### *8.2.3 Tool Appropriation*

Rather than explicitly supporting new workflows within the production process such as rush editing or continuity processing, StoryCrate was designed to present a set of atomic tools to the crew, which could be re-appropriated to perform a variety of editing, playback, meta-data recording and storage operations by crew-members. In designing to support this (re)appropriation, I designed each tool to be distinctive in its functionality and removed some functions from the system to produce a set that were more easily repurposed. An important consideration in the design of these tools was to avoid enforcing a particular team structure in the use of StoryCrate, that is, the individual tools had to be designed to allow the team to re-appropriate them to meet the team structure adopted (thus even democratic team structures could not be implied in the design). The nature of the professional specialisation amongst the crew was also a consideration in deciding which tools to include in StoryCrate. The replication of the functionality of existing equipment would have been viewed as superfluous by the crew, but also as a replacement for their role in the team, creating a professional animosity towards any new technology. Some members of the team already felt they had enough creative input into the workflow without the need for external representations of their contribution. In conclusion, StoryCrate was designed with a limited atomic set of functional elements that could be re-appropriated by any member of the team to in the completion of different tasks. In practice, the team quickly adapted to the presence of StoryCrate, primarily by the assignment of an operator. Although unexpected, the atomic elements of StoryCrate allowed this workflow to continue through a proxy operator.

## 8.3 Supporting Heterogeneous Teams

*"How can heterogeneous teams be supported in their production roles by collaborative technology to drive an improved attendee experience?"*

### *8.3.1 Designing for a Variety of Team Skill Levels*

ProductionCrate was developed to engage non-professional members of a community in the production of dynamic and relevant multi-media content for a situated event. In community of interest events such as those in which ProductionCrate was deployed, the roles of producers of content and consumers of content significantly overlap. In ProductionCrate I aimed to leverage this overlap by providing production tools which assumed a level understanding of the event content by the crew members in order to inform the editorial decisions made during the event. Additionally, with community submitted content driving the media narrative, the roles of media producer and media consumer are entangled. Multi-skilled non-production crew can now be engaged in content development and the production workflow in environments where situational factors such as technology complexity and size would have previously been unsupportive to this class of workflow. ProductionCrate used touch, mobile and web technologies to bridge this gap through tools to make production processes easier and more intuitive for crew members unskilled in production tasks. Using collaborative interaction tools based around individual simplified production workflows, I bridged the complexity gap between professional-level and consumer-level tools to facilitate a cohesive yet multi-skilled production team. Rather than introduce cutting edge interaction technologies to these hybrid attendee crew members, I deployed well known and robust interaction technologies such as single touch displays, tablet applications and web based interfaces. My design and deployment of ProductionCrate has highlighted the complex design problems and social constraints apparent within this production context, and did not necessarily perform as expected within each deployment. The lessons gained from these in-the-wild studies are invaluable however in  defining the key design considerations for systems that support such a complex workflow. In designing such tools, The wide range of skill levels that are present in a team of non-professional production crew necessitate technologies that are analogous with those found in existing consumer tools. This reduces the learning curve and allows production tools to leverage everyday media production skills.

### *8.3.2 Supporting Teamwork for Production*

The production processes that were required to produce and maintain the output of a community event by necessity had many roles requiring different levels of skill. These roles were performed by hybrid-attendees, people who moved moving between the role of attendee and production crew during the event. In this context the maintenance of a coherent media narrative throughout the event posed significant challenges. Benford's framework of participant 'trajectories' can be used to describe the role changing that occurs within this type of production team, although this implies master 'director' who is responsible for maintaining a constant narrative and continuity across the event. I discovered the individual production workflows facilitated by ProductionCrate supported the crew to move in and out of the same role (given long shift patterns), but that the crew lacked a coherent view of the rest of the production as these tools were 'session' based, and did not present a view of the directorial decisions made outside of the current session. Without a persistent content director, continuity was lost between different periods of directorship and content production. Decomposing production workflows did however support user's completion of succinct tasks in the knowledge that they had contributed to the overall production, and using particular technologies for each of these tools allowed the tailoring of interaction techniques to the level of skill level of the users operating them. As for the case of StoryCrate, ProductionCrate aimed to promote awareness of the current directed narrative to members of the team. Since this team was spread across venues, the primary vehicle for promoting awareness was the rapid production loop itself, which was supported by viewing content on media outputs in the venues of the event. ProductionCrate, although aiming to provide this feedback as a rapid and responsive cycle did not provide a fast enough response loop for either the production team or attendees, particularly for social media. ProductionCrate demonstrated the value of such a loop, but future systems should consider both the implementation of this loop and how this feedback is presented to the production team to avoid temporal sticking points in the workflow. Additionally, verbal communication provided a backbone of social and work related communication through which questions could be asked. In conclusion, communicating a coherent narrative using a group of non-skilled and spatially distributed crew-members is a difficult proposition but was facilitated by ProductionCrate using individual workflows and consumer-level technology targeted at specific production tasks.

### *8.3.3 A Hybrid-Production Team to Drive Quality*

The design of ProductionCrate and my analysis of the two deployments revealed that non-professional crew perceive their own practice and assess the quality of their output in different terms to that of professional media crew. By designing tools that support these non-professionals in performing production tasks, I demonstrated that hybrid-attendees *can* bring elements of production quality to the media output (such as content selection and routing decisions) with more contextual understanding, that are less relevant to professional production teams (i.e. not part of the COI). In particular, crew with a personal stake in the outcome of the event, and an intellectual stake in the content and discourses of the community, made production decision that are informed by their domain-specific understanding of attendee expectations. As revealed in the two deployments however, there are a number of barriers to fulfilling this state of true hybrid-attendee interaction. Foremost of these is the need to balance the amount and learning requirements of new technology and processes given to hybrid-attendees against the potential value gained from their participation. Clear examples of a failure to design tools that were appropriated in this context are the interfaces for adding questions and relating tweets, operated by student volunteers which were quickly dropped from use during the event, thus loosing temporal relevance and value to the event. In any COI event there are a limited number of available people to use in the production team. As we discovered, responsibilities to event management tasks came before production tasks, resulting in a lack of engagement in some elements of ProductionCrate. The design of the Rapid Video Editor and Tablet Controller demonstrated that the design of small, self-contained workflows, with clear methods of feedback for each production sub-task, supported each user's perception of influence over the event. However, future designs should anticipate the need to provide access to other event content during these tasks to give users a wider contextual understanding of how their tasks fit within the whole event. A key understanding revealed by the deployments is designing for crew 'down-time', that is, designing batch tasks not suitable to be performed during event sessions which can be accomplished during times of low activity and do not prevent attendees from participating in the event. In conclusion, hybrid-attendee production teams *can* be facilitated and supported to produce content which is more relevant to an event by designing tools which allow them to engage as attendees during the event whilst performing production tasks. These tasks however need to be carefully designed to make good use of event 'down-time' and without introducing large amounts of technology of any kind into the attendee experience. It is key that these technologies do not expect too much engagement from attendees and production systems can re-configure to a dynamic crew structure created through non-use of equipment.

## 8.4 Designing for Situated Production

*"How can we design collaborative interaction for situated media production and the situational factors that impact on these contexts?"*

### *8.4.1 Technology Aesthetics*

Both StoryCrate and ProductionCrate were designed with a specific visual and physical aesthetic, primarily the use of 'flight case' style hardware and fittings. This aesthetic was designed with previous production technology in mind, and primarily in response to the environmental requirements of the deployment environments. Both technology designs were heavily influenced by the practical constraints presented by in-the-wild deployments in relatively unknown and un-predictable environmental conditions. The measures undertaken to design for these factors were taken from existing production technology, and included heavy-duty fittings, transport cases, wheels and cable-based connectivity where appropriate. The use of 'flight-cases' is also a response to the need to transport a technology within the confines of a standard freight shipping (J. Richards, 2006). Through the necessity of moving the deployments to a variety of different locations, this defined how each technology configuration would be distributed amongst cases and storage units. The flight-cased aesthetic is traditionally associated with robust and well-worn technology that has remained un-changed for many years, but within the deployments the look and feel of the equipment was also interpreted as a 'work-in-progress' design that gave the impression that it was 'unfinished'. Rather than make users reluctant to interact with the technology, this 'unfinished' aesthetic actually encouraged conversation and discussion around the technologies by allowing users to conceive that there could be a better solution available.

Users were also found to be more forgiving of bugs in software and hardware simply because the devices did not look like 'finished' products. The design integrated software in each device was given the same 'flight-cased' treatment as the hardware to avoid single failure points. As such, each device was designed to continue running independently on networking or communications failure, and when failure did occur, devices would automatically restart and retain their last state. Once deployed, more interesting features of the 'production' technology aesthetic were revealed, particularly in relation to professional considerations. Professional production crew such as those who used StoryCrate have an affinity to specialised media technology that is different from consumer products. These systems are seen as 'pro' tools that require skill and experience to operate. As such, introducing consumer 'looking' hardware into their domain would encourage judgements of the technology as 'mainstream' and therefore not of professional quality. By developing new technologies which maintain the professional aesthetic, professionals are disposed to engage with it more positively. In contrast, amateur production crew such as those using ProductionCrate can be intimidated by too much 'pro' technology, but when deployed in managed quantities, the professional aesthetic can encourage non-professional users by making them feel professional (and therefore act professional), and feel like legitimate members of the production team. In conclusion, my case studies demonstrate that technology aesthetics have a huge impact on the uptake of technology deployed into situated production environments, both in terms of the connotations of professionalism and the response to this by professional and non-professional COI users, and the environmental constraints that define physical robustness and each of deployment of the systems.

### *8.4.2 Data Maintenance*

In both case studies it was discovered that the systems responded well to the changing work patterns of users and were supportive of random access to all available media. An expected side-effect of this supporting random access was the need to perform simple periodical maintenance tasks on incoming data, such as when Tweets arrived into the ProductionCrate system or when clips were automatically added from the camera into StoryCrate. Through the act of performing maintenance tasks, users experience a wide variety of the production content, and this can be used to engage users that might not be as active in the production process (such as the lighting engineer for StoryCrate). The hope was that with StoryCrate, the team would reconfigure dynamically to fulfil this maintenance need, whereas in ProductionCrate, the role would be explicitly allocated according to a rota. In practice, the ProductionCrate team did share the maintenance role amongst the team, but each team member lost motivation to perform the role diligently, resulting in vetting and routing issues. For the StoryCrate deployment, the ream recognised early in the process that maintenance would be required and so created a new production role to fulfil this need (bringing in the Runner to perform it). Subsequently the Runner became a gateway to the interface. Future designs should consider carefully the available time that members of a production team can feasibly give to 'spontaneous' interaction with such as system. One solution may be to design production systems that require less maintenance. This approach was in part used in ProductionCrate, where some of the personal production workflows included smaller elements of maintenance. However, I would also argue that designing the production workflow to remove the need for on-going maintenance removes the opportunity for personal and creative engagement in media content as it is arriving into the system. To conclude, I found that it is vital to consider the impact of additional tasks that are introduced in to the workflow by new technology by maintaining a shared representation of the state of the production. Reducing the number and complexity of maintenance tasks is one solution, but this approach may result in a lack of rich media being available in the system for users to engage with.

### *8.4.3 In-the-Wild Deployment*

The development and deployment process used for both StoryCrate and ProductionCrate was a process of better understanding of the situated teams and their production workflows. Overcoming technological and deployment challenges whilst performing this research has provided deep insight into the complex situational factors that are apparent in these domains. Reflection on the deployment processes required for these studies yields an understanding that is valuable for future design and deployment activities. As is often the case in multi-disciplinary research labs, researchers are called upon to provide observational, logistical and debugging support for deployments. Both StoryCrate and ProductionCrate presented huge logistical challenges in this area requiring multiple observers, documenters and support staff. Support from the BBC allowed us to create a layered observational team consisting of researchers who were not part of the StoryCrate development process; but ProductionCrate presented a distinct set of challenges for this type of observation strategy. The development process for ProductionCrate entangled the organisation of each community event (as is the nature of action research) with the task of designing for and with prospective users of the system. Members of my research team performed three different roles during the event: i) event organiser; ii) ProductionCrate media team member; and iii) research, performing observations to analyse the use of ProductionCrate and the impact on attendees. In such as large operation, it was not possible to spread these roles amongst people without multiple conflicting roles becoming a necessity. Additionally some of these roles held precedence over others (with the delivery of core feature of the event taking priority over all others). By involving the crew, researchers and observers in the analysis process, the inherent complexity of these roles has been leverage to gain valuable understandings, but these roles still have to be understood to contextualise personal experiences of the deployment. These challenges are not commonly discussed in research that focusses on deployments, but especially in situated media production, and form a large part of the planning process and must be considered during the design and implementation phase of any technologies. One important factor to consider is the requirement for on-site technical support for deployed technology. This usually involves technically able researchers being available across any locations in which technology is deployed, but without having another role to perform.

In conclusion, while it has been demonstrated that it is beneficial to perform research in a domain in which the researchers are skilled to aid understanding of the scenario, it is important that there are clear definitions between who is a researcher, who is a production team member and one who is a ‘consumer’ or ‘attendee’. Without a caveat however, this distinction is contrary to the notion of hybrid-attendees and the duality of their role. In these complex cases, the distinction between roles can be blurred, but it is key to still maintain a separation between those performing observations (gathering data), those participating in the event as traditional production team (professional crew), and the newly defined group of hybrid-attendees. In the case of ProductionCrate, these roles intertwined resulting in nuances of the data being lost. Interestingly, during analysis phases, I found that it was helpful to bring these groups together to drive discussion and fill in a wider picture of the event from numerous perspectives. As these deployments have demonstrated, in-the-wild deployments are a vital practice in understanding the impact of technologies within complex environments, but only by treating these deployments in terms of experimental observation can we take these findings and generalise them to other domains and application areas.

## 8.5 Future Work

The designs for collaborative production technology presented in this thesis are clearly targeted at specific situated media production scenarios with particular associated situational factors. Advances in interaction technologies, particularly in tangible and multi-touch are continuing, and these new forms of interface could be appropriated to develop production tools. For example, position dependent haptic feedback for touch screens for example could be used to develop reconfigurable interfaces that do not need the operator to look at the display to perform tasks, however, my primary concern is to consider the transferability of the insights gained as to the nature of situated media production, and their applicability to the changing nature of media itself.

The situational factors that define the two scenarios in this thesis can be found across other similar media production environments, and even within other teams in these environments. The filming stage of a TV production is just one of many required to produce a finished product. Other stages may also be categorized in terms of key situational factors, such script writing or post-production phases and as such may benefit from collaborative interventions to improve their output. As well as taking the designs revealed in this thesis into other situated production teams who produce video and social media content, these can be applied to the design of tools to support other types of production teams, such as lighting, sound and logistical teams within the same scenario to test the validity of my claims, particularly in response to situational factors present across multiple teams. In particular, the use of tangible and physical controls would allow eyes free interaction and support similar types of tactile interactions that production technology already presents to users (such as lighting and sound desks).

Within professional broadcast networks, new forms of media production are emerging which make use of in-line interaction and user generated content to deliver multi-format, multi-device, multi-narrative programming. Recent examples include the 2012 London Olympics in which second screen applications, social media streams and on-demand footage were integrated into a viewing experience across the web, mobile and TV in real time. These emerging forms of content delivery present unique challenges for the production of content, especially at the point of capture. Collaborative tools such as StoryCrate could facilitate web-designers, mobile designers and print media journalists (who would normally be given static content to work from in post-production) to contribute to the real-time capture of video, adding meta-data or reformatting content relevant to their respective outputs. This type of collaborative tool could be used to introduce multi-skilling and dynamic role distribution and support more responsive workflows.

Collaborative production mobile applications are emerging in response to the increased capabilities of mobile computing platforms. These platforms leverage the situated nature of individuals to capture and share footage from events that would not have been possible using traditional production technology and workflows. The design recommendations for co-located interaction and decomposed production workflows from this thesis can inform the design of these types of applications to improve the quality and availability of such tools. In the deployment of ProductionCrate, social media feeds became an important part of the production workflow, as both a backchannel and direct media output. Further work also could make direct use of these communication channels for the production team, providing transparency for attendees, and a rich way of communicating amongst the production team. More radically, social media feeds could be used to replace specialist production infrastructure (such as video streaming hardware) to provide an entirely reconfigurable (and decentralised) production infrastructure.

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