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Bootlegger: Turning Fans into Film Crew

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ABSTRACT
Bootlegger is a system for creating multi-camera films of live music events using mobile devices. Using readily available technology and a synthesis of film-making conventions, the system coordinates music fans at live shows into an improvised film crew, suggesting shots, collating footage and generating rich metadata in real time. Bootlegger is part of a research project exploring adapting professional media workflows to amateur contexts in order to lower the bar to entry for media production. By enabling concert-goers to contribute to high-quality concert films, the system leverages mobile phone 'bootlegging' practices to support emerging musicians.

Author Keywords
Mobile, DIY, bootlegging, user-generated content, amateur video, digital video

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous;

INTRODUCTION

SiDE (Social Inclusion through the Digital Economy) Creative Media is a research project exploring how technology can be used to empower communities to tell their own stories via professional-quality but amateur-led media production. The project is especially dedicated to developing frameworks that enable young people to learn digital skills and engage with the creative industries.

In this paper we describe Bootlegger: a system that supports musicians and their fans in creating high-quality multi-camera concert videos using their own mobile devices. The system leverages 'bootlegging'; the growing phenomenon of music fans recording mobile phone clips at live music events. It connects fans with their favourite artists by establishing a collaborative video production workflow around a live concert, the results of which can then be edited by the artist and used to promote their practice.

In recent years, developments in digital music technology have meant that emerging musicians have become increasingly able to produce, record and promote music themselves, without financial and logistical support from studios, promoters or record labels [1]. The ease of use and availability of laptop recording software has led to an unprecedented democratization of music production, a domain once almost entirely controlled by record companies [2]. This revolution in digital music production has been mirrored by similar developments in photography and video technology; consequently, the technical means are becoming available for emerging musicians to produce professional-quality visuals to support their music.

Videos of live performances are considered particularly desirable artefacts [3]. Consumed by fans as an entertaining aesthetic experience in themselves, on similar terms to an artist's musical recordings [4], they can also form a documentary and promotional role, testifying to a performing artist's capabilities, demonstrating their stagecraft and ability to engage audiences.

Bootlegger explores whether mobile technology can assist non-professional film makers to make high quality concert videos by enabling them to adopt workflows and conventions from professional film and TV practice. Deployed on concert-goers' mobile phones, Bootlegger acts as an automatic director/producer, coordinating music fans into a tightly-organized production team. During a live show, the system supports and instructs audience members in capturing a range of shots. These shots are assigned according to a scheme that prioritizes coverage and visual consistency: as one user is asked to shoot the lead singer in close-up, another might be asked to cover the entire stage, while a third might be tasked with capturing detail shots. At the end of the event, footage is uploaded to the cloud and is accessible directly by the artist or band for editing. In this way, fans are rewarded for their time and effort by being able to take a genuine and active part in their favourite artists' work.

CONTEXT

Using the internet, musicians are also now able to distribute their own music via subscription services such as Spotify or download sites like iTunes [5, 6]. Without the need to raise capital to press records or CDs, musicians whose practices generate little or no income can sell their work alongside multi-million pound media companies [1]. This shift in business models has led to an explosion of creativity in the music industry, with more musicians than ever before able to market their music to an increasingly global audience. Over 20 million tracks are available through Spotify alone,

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many of which are submitted by musicians without record company support [6].

The world-wide web now accounts for the majority of global music sales and live event promotion [1]. Online platforms such as Reverbnation [7] and Bandcamp [8] offer elaborate web platforms geared specifically towards musicians with integrated downloads, media streaming and e-commerce facilities to support promotion, sales and audience recruitment. These sites effectively combine the roles of record company and record shop in enabling musicians to bring their work to audiences.

Despite these developments, audience numbers have not swelled to match the volume of music now being produced, and artists face increasing competition for listeners [1]. As a consequence, there is a rise in the professionalization of music at grass-roots level, where musicians increasingly attempt to distinguish themselves from their peers through promotion with high-quality images and videos [2]. Electronic Press Kits (EPKs) are becoming an increasingly popular tool for dealing with venues, promoters and booking agents, containing press-releases, high quality photography and video clips.

Planning, shooting and editing a coherent and visually striking music video is a complex task. Not only does it require a detailed knowledge of camera operation and the conventions of TV and cinema but it also necessitates planning and resources. Even live music videos shot at a single venue require substantial organisation, generally requiring a crew of trained camera operators and specialist equipment. Commissioning this type of production is expensive and beyond the resources of most emerging musicians. However: the rise of music and video streaming services has also resulted in a huge surge in another form of music video: the unauthorised fan recording, or 'bootleg'. Millions of music fans every year upload clips of their favourite artists, captured using mobile phones taken at live concerts. This phenomenon is usually spontaneous and rarely coordinated [9].

Unauthorised recording is hugely controversial among established successful artists, with a number of high-profile musicians claiming that illegal recording damages their reputation, infringes their copyright and affects their income. Kate Bush, during a recent series of concerts asked concert goers to refrain from recording clips of her performances, apparently concerned that poor-quality recordings would undermine the promotion of her shows [10]. Other artists have expressed concern that the phenomenon of fan-recording damages the concert-going experience, as concert-goers block the view of others with mobile devices. Among emerging artists however, who have yet to establish income from their music, financial impact is close to non-existent and many grass-roots musicians recognise that online clips can be a valuable source of free promotion and publicity [11].

Several online services have already begun to leverage mobile phone bootlegging practices, in order to both encourage fans to support their favourite artists and to make available an inexpensive source of video footage that musicians might use themselves. Some of these services attempt to overcome the problem of low-quality sound while co-opting fans as a source of footage for musicians' concert videos. FanFootage.com [12] (formerly 45sound) provides users with the opportunity to upload footage of live shows, which is then automatically synchronised with high-quality sound recordings provided by the artist. The resulting video can then be viewed on the artist's Fanfootage page. Similarly, Vyclone [13] uses basic synchronisation to enable small numbers of mobile phone users to make multi-camera films from aggregated content, via a simple online editing system.

Some musicians and bands have directly leveraged bootlegging activity to engage fans and generate novel video content. *Awesome, I fuckin' Shot That* was an experiment by the Beastie Boys in which 50 DV camcorders were loaned to members of the audience during a show at New York's Madison Square Garden [14]. The band Nine Inch Nails applied a similar strategy to the editing of live concert footage in their project *Another Version of the Truth* [15] in which professionally shot footage was made available to fans through the internet. The resulting amateur edits were then packaged and marketed by the band.

Services like Fanfootage and projects like *Awesome* suggest ways in which musicians can draw upon the creativity of their fans, however this engagement is limited, occurring only at the point that the video is shared. While the musician has no say in the specifics of what is recorded (beyond the broad context of the concert), neither does the fan have any idea if what he or she is recording is of use. An artist soliciting footage from fans with no video training has no guarantee that the result will be aesthetically acceptable in terms of framing and composition. Without radio equipment, communication between fans across a venue during an event is practically impossible; consequently there is also no way of ensuring that a sufficiently complete range of angles will be captured. Without a unified scheme for logging shots, collating a body of fan footage remains a time-consuming manual process. A number of HCI projects have provided insight into sharing media via mobile devices. Esbjornsson et al. [16] developed a mobile application for motorsport fans to exchange live images and information about rally events, in order to more fully connect spectators to the action. Flintham, Reeves and Durrant [17] developed a system enabling spectators to share live video of marathon events to augment traditional broadcast media, or in the case of small-scale events where TV coverage was inappropriate, replace it altogether. Once again, however neither of these projects dealt with the aesthetic quality of the resulting footage.

In developing Bootlegger, we propose that a more effective method of engaging fans in recording an event is to take a directorial approach: where fans are coordinated centrally on a moment-to-moment basis as they use their mobile devices. Moreover, by incorporating some basic tuition in cinematography into Bootlegger, we ensure that a range of well-composed, aesthetically coherent shots are captured.

Other research in HCI has suggested strategies for integrating cinematic conventions into multi-camera movie making. Lino et al. [18] have developed a number of applications that apply cinematic conventions to the control of virtual cameras. Lino et al.'s Director's Lens project also tutors users in shooting virtual dramas through suggesting various shots according to templates [19]. In terms of parameterising the overall structure of a video, The *documatic* project [20] involved automatic generation of the entire structure of a video via similar generic means while the *Cinejack* project [21] investigated automatically controlling the narrative arc of a video via interactive editing. Lastly, Engström, Esbjörnsson, and Juhlin [22] suggest ways to coordinate of multiple mobile devices in live music environments.

Concert videos have been a popular documentary form since the 1960s and tend to conform to genre conventions in both style and content. Many of these, such as how to frame the human body are common to cinema in general and are detailed at length in film-making texts [23]. Others are peculiar to the genre and extend from choice of subject and type of shot to the overall structure of the film. As part of a project on video indexing, Snoek, Worring, Smeulders and Freiburg [4] identified a small range of common shots common in concert videos and attempted to use these to classify over 100 videos shot by shot.

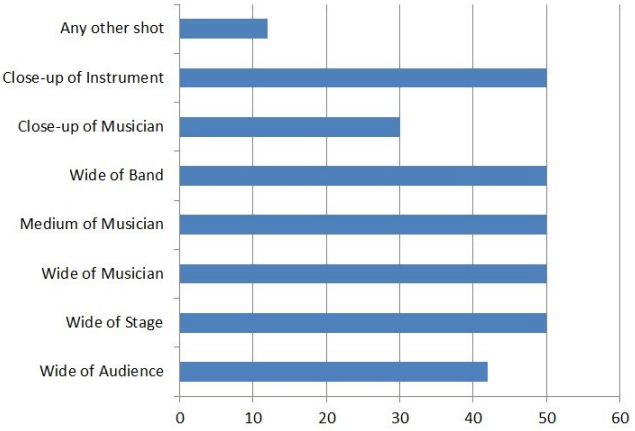

Figure 1. Shots included in the 50 videos surveyed.

In planning Bootlegger, we built upon this approach, conducting our own survey of over 50 concert videos across a number of genres, including rock, country, folk, hip-hop and metal. These videos were selected as representing the broadest possible range of directorial approaches, incorporating differences in venue size and type, context (e.g. festival, TV live set, and individual concert), production values and type of ensemble. In each of these videos we noted each shot type that occurred, resulting in an exhaustive list of standard shot types.

We found a remarkable similarity in directorial style across all these videos, with more than 38 being composed exclusively from 7 types of shot and only 12 containing shots other than these (see figure 1). This suggested that a generic music video template might be relatively simple to compose. This list of shots became the basis for designing the Bootlegger direction system.

DESIGNING BOOTLEGGER

Bootlegger explores how technology can be used to enable non-professional film-makers to make professional quality concert videos. Drawing on the authors' experience and prior work [24, 25] in working with live production crews, we adapted workflows and conventions used by professional film and TV to organise concert-goers into ad-hoc production teams.

In a traditional video production team, camera operators are typically led by a director who has an overview of what each crew member is able to capture. In ideal circumstances, such as in a dedicated TV studio, a director shooting a live event has both an overview of what each camera is capturing (usually via a set of monitors) and moment to moment contact between crew members, often via radio. Bootlegger was designed to fulfil this directorial role, assigning different shots and subjects to each camera-operator by monitoring their current availability in order to provide possibilities for the editor.

Typically, the role of a camera operator is to apply their own knowledge according to the director's brief in capturing the subject. As both director and camera crew have a shared technical knowledge of film-making convention, this brief can often be as concise as 'get a close-up of the singer'. The camera operator, from training and experience, knows exactly how to compose each shot and what position they need to be in and needs no further information. In organising non-expert mobile phone users into a production team, it could not be assumed that the camera operators would know how to compose each shot. Bootlegger was therefore designed to guide camera operators by displaying generic compositions alongside each set of instructions.

To ensure that the design of the system would be appropriate to its users, we also collaborated with a number of early-career musicians throughout the project. Bootlegger's development team used discussions with these artists to design the system, which was then tested and evaluated incrementally at the artists' live shows. We also asked the participating musicians for their views on concert videos, in particular, what a concert video should seek to achieve, what types of shots to include in the system and what they might use the resulting videos for. We found

from these discussions that the artists' chief source of anxiety over audience members bootlegging their work was not copyright infringement or loss of revenue but quality and control over footage. One musician posed the question,

"I think the main concern, I'd say, from an artistic point of view, would be: what if they do a bad gig, and you get this footage of a bad gig?"- Musician

Sound quality was a particular concern as mobile phone microphones are often unable to cope with the high audio levels at amplified concerts.

In summary, the Bootlegger system needed to be enjoyable and simple to use, requiring little conscious control or organisation on the part of the user. Shooting live music events presents unique challenges to the film-maker. Live music shows invariably feature low light, wildly varying sound levels, crowded environments and unpredictable subjects. It was imperative therefore that Bootlegger be easy to use in a confusing, noisy environment. The system would need to be able to handle the moment-to-moment complexity of maintaining visual consistency and total coverage while providing enough variety in its tasks to prevent users becoming bored. An uncluttered UI and simple controls were necessary, as were a minimum number of steps in the login and start-up procedures. As live music events take place in a wide range of venues, it was also necessary that Bootlegger be agnostic to the varying availability of mobile network infrastructure.

The design priorities behind the system could be summarised as follows:

1. To ensure the aesthetic quality of footage on a per shot basis.
2. To maintain maximum coverage of all subjects across all cameras.
3. To streamline the editing process by producing metadata for each video clip shot.
4. To ensure that using the system would increase, not diminish users' enjoyment of the concert, through an increased engagement with the artists.

IMPLEMENTATION

Bootlegger is implemented as a client-server infrastructure. A central server-based node.js Sails MVC application backed by a no-SQL Mongo-DB data store and Amazon S3 file store server acts as the event camera director maintaining all real-time shot allocation logic and event metadata. This application can be horizontally scaled to meet the size or volume constraints of current events. Bootlegger users becoming members of the film crew download a native mobile application written in the cross-platform Xamarin framework. This application sets up a consistent and robust real-time bi-directional communication link via a web-socket to the server API. As consistent network signal cannot be guaranteed in live music venues, only small JSON control messages are sent between the server and mobile device, reducing the bandwidth requirements and latency for directorial decisions.

Event Template

Bootlegger's design relies largely on abstracting the conventional structure and production practices of live concert video production into configurable parameters. In Bootlegger, the genre and cinematographic conventions of each type of live event are defined in an *event template* (e.g. live concert). The template defines parameters generic to music events that can be edited by the event organiser (see Figure 2), such the names of performers and their approximate location on stage, which are automatically included in instructions to the camera operators (see Figure 5).

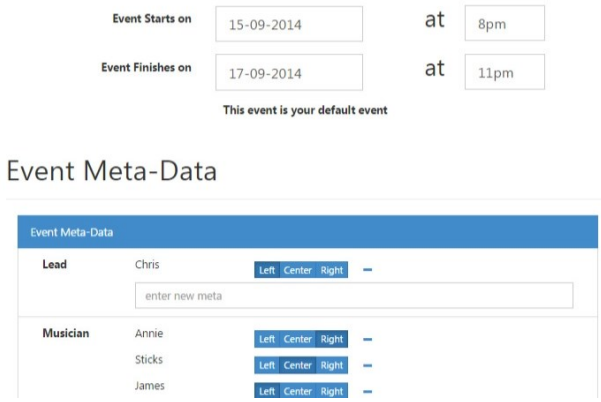

Figure 2. Setting up an event in the web application.

The template defines a hierarchy of 3 key parameters, *roles, subject classes* and *shots* (see Figure 3). Roles describe possible camera positions of a crew member in the venue and a list of shots that could be taken from this position. Upon choosing an event, users are asked to select a rough physical position which matches their location: close to the stage, in the middle of the audience or at the back of the venue. This position determines which shots are included in a palette of possible allocations. Users taking the close role are mainly asked to capture close-up and detail shots, whereas wide shots are allocated to users furthest from the stage.

This selection is deliberately broad, taking into account that both musicians and fans might move around during the show and that stages might be configured in very different ways: the approach works with any configuration where the musicians are located in the same space, regardless of the size or layout of the venue. More precise electronic location of either users or musicians is not attempted, again due to the likelihood of poor network infrastructure at music venues. To add context to the resulting videos, roles are also available which include the outside of the venue (to cover audience or band members arriving) and backstage areas (requesting contextual shots of musicians preparing to perform).

The percentage of total shots that should be devoted to each *subject class* is also defined in the event template. Subject classes describe the subject of each shot: lead musician, supporting musician, detail or audience. In the live music event template, generic rules are applied: for example, the majority of shots should be of the band, of which more than 50% should be depict the lead musician, while only 5% should be shots of the audience.

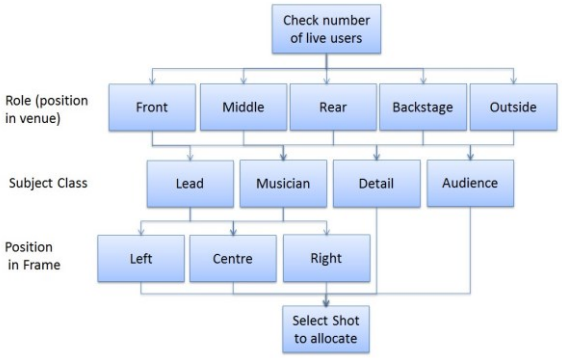

Figure 3. Shot allocation logic in Bootlegger

The *shot* definition describes each individual clip requested and references a semi-transparent image overlay (see Figure 4), and a text instruction which is displayed in the camera view of the mobile application. Each overlay and description demonstrates to the user a conventional framing that might be included in a professionally-shot live concert video. In order to ensure a spatially coherent series of shots, the shot type definition also references how the subject should be framed in every shot: whether to the left, the right or the centre of the frame. Consistency of framing is a key factor in maintaining spatial legibility across the whole film.

Auto-Director

During the event, the server timing algorithm uses the information in the event template and the current state of each user to constantly assess who is live, which shots have already been allocated to which user and how long they have left to record, (see Figure 6).

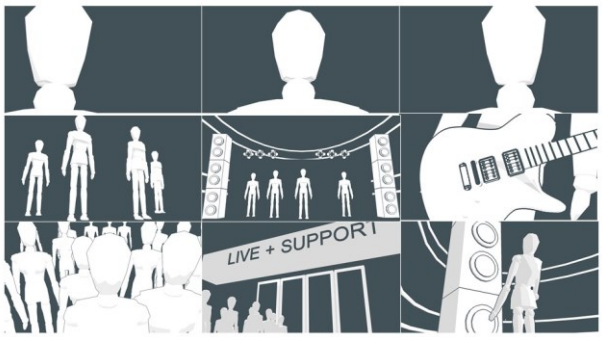

Figure 4. A selection of overlays for different shots

If only one operator is left it asks that they record continuously, in order to avoid gaps in coverage. After each recording, a thumbnail and all associated metadata is uploaded to the server allowing the shot allocation logic to maintain an accurate overview of available footage and crew availability.

After the event the user uploads their footage over WiFi at their leisure. Crucially, the footage is uploaded to the event organiser's account and then removed from the phone, enabling the user to contribute their footage to the event, whilst allowing the organiser (usually the artist) to maintain control of the video.

Mobile Application

The mobile application is designed to be lightweight and agnostic to both events and shot allocation logic. On connecting to an event, all shot overlay assets are automatically downloaded to the local device (to save bandwidth). Any member of the team hitting a start button triggers the event system to start, at which the Bootlegger auto-director begins assigning shots, according to each user's role and current status. After selecting a shot, the user is counted in (over 5 seconds) and a fixed recording period is initiated (around 25 seconds per shot). Recording is initiated remotely in staggered phases across the user group to guarantee maximum coverage. After each recording phase ends, the auto-director immediately offers another shot, waits for a few seconds for the user to accept or reject it and then begins the recording cycle once more.

Besides the overlay (which can be turned off if the user desires), the camera interface is superficially similar to standard mobile camera applications and is designed to help users obtain a clear unobstructed view of the capture target. Digital zoom is restricted to 2x, to retain as much image quality as possible, while a tilt indicator appears on screen if the camera is rotated away from the horizontal. Users are informed via an on-screen message whenever new operators join or leave the crew.

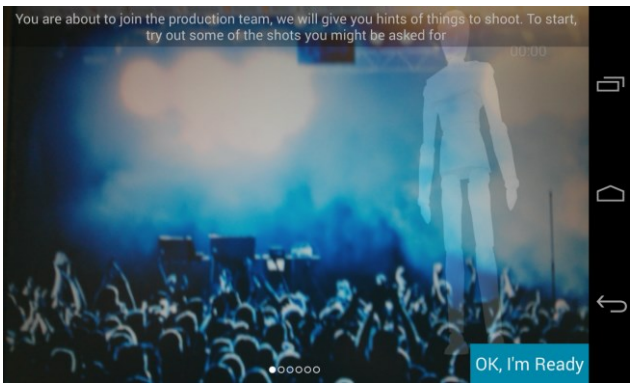

Figure 5. Bootlegger's UI, showing an overlay.

Event Administration

The server's HTML5 web application allows event organisers to monitor a production in real-time. Figure 6 shows the interface for the application. Moving coloured bars show the state of each camera (recording, allocating a shot or waiting). As each clip is captured, a thumbnail and corollary data become available to view.

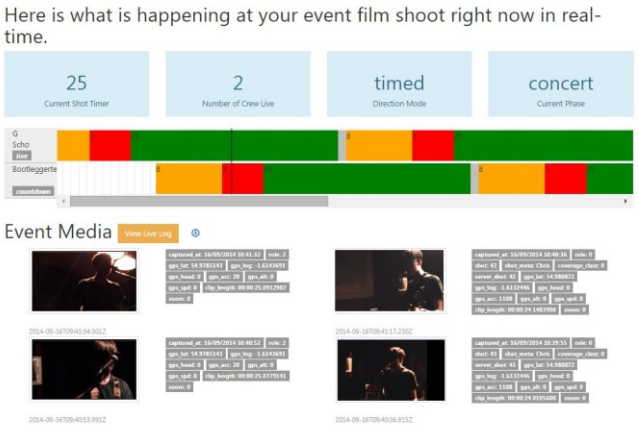

Figure 6. A show in progress, showing current state of each user and incoming metadata

An advantage of using smart phones over conventional video cameras is the potential for appending metadata to the footage, to aid navigation of the clips and streamline the editing process. During capture, each clip is tagged with the identity of the current user, their role, the shot type and subject requested by the auto-director, zoom level, rotation of the device, clip length, timestamp and any available location information. This information is aggregated by the server and can be downloaded as a detailed shot-list with thumbnails of each clip to aid logging and editing, or as an approximated Final Cut Pro XML Edit Description List (EDL), which can be loaded into FCP or Adobe Premiere. The editor is presented with each clip and its associated audio, arranged track by track in temporal order, simplifying a normally time-consuming manual process.

Audio Synchronisation

Although smartphone camera technology has advanced considerably in recent years, microphones in mobile devices and video cameras are often not suitable for recording live music. As sound quality is an important factor in concert films, it is envisaged that Bootlegger event organisers would take a separate audio recording of the event, either from microphones in the venue, through the event's Public Address system, or ideally a combination of the two. As precise audio synchronisation can be a difficult and time consuming task, Bootlegger's server application enables the user to upload a high-quality audio recording of the event as a synchronisation reference against which each video clip is checked and assigned a precise start time. This processing step, building on an approach by Orfanidis [26], can be used to generate a far more precise EDL in which all clips are synchronised exactly.

DEVELOPMENT IN THE WILD

As a system designed for chaotic environments, Bootlegger was developed as much as possible 'in the wild' with each design iteration tested at real music events. The design of Bootlegger, from a basic specification drawn up through discussion with the participant musicians, was developed over several phases, each of which was tested at their own music shows by volunteers and friends of the bands. This approach, suggested by Rogers et al. [27] and Taylor et al. [28] was used to ensure that at every stage, the system could support users to capture high-quality footage under real-world conditions.

This iterative design cycle relied on developing fully functional prototypes which could be used by concert-goers. Choosing to test each version of the system at live music events meant that we had no control over the layout, lighting and atmosphere of venues, behaviour of the bands and audiences or characteristics of the sound. As all the test events were at small venues ranging in capacity from 50 to 300 people, this usually meant coping with poor lighting, unusual stage layouts and a lack of space for camera operators to stand. The unrepeatable nature of each event coupled with the necessity for uninterrupted coverage of each track meant that failure of the system, even for a moment would render even well-shot aesthetically pleasing footage unusable. Stability and robustness of the system was therefore paramount at each stage.

'Camera crews' were recruited largely by the musicians and were shown the system for the first time in the hours before the test event. At each show, the fans were asked to record the entire show if they could: a task that would both test the system as thoroughly as possible and would also generate the maximum amount of test data and video footage. After each show, the 'camera crew' were interviewed and the footage manually edited by the authors into a music video. These videos were then used as a focal point for discussion with the musicians who were asked specific questions relating both to the quality and variety of the output. The resulting information was then fed into the next version of the system.

At each event we used a range of Android mobile devices with all with different HD cameras and technical characteristics. We also deployed 2 entry-level MP3 recorders; to record ambient sound and the direct feed from the venue PA system. A mix of these two recordings was used for the audio of each video project, with audio from mobile devices used only for synching clips to the edit.

The first of the test events involved a country/folk band at a local bar venue. 5 users were given phones running the application immediately before the show. After a short explanation by the development team, they were asked to film the band's entire 25 minute set, focussing particularly on 3 tracks that the band were keen to have featured in live videos. Discussions around the resulting video prompted several further developments to the system. Although Bootlegger was designed to avoid the need for a high-bandwidth network connection, a weak 3G signal is necessary to maintain connections between each phone and the server. Poor 3G coverage at the event (the show was in a thick-walled basement venue in an industrial building) led to minimising even further the system's reliance on network infrastructure. A high stage meant that close shots were

difficult to attain, necessitating an increase in the allowed range of digital zoom. One operator filmed the entire set with the phone held upright, suggesting that the system should sense the device's orientation and prompt users if they were making this basic error.

Further testing was carried out at a local music festival, with 6 volunteers covering sets by an indie-rock band and an electronic act in two different venues. Once again, both sets were filmed in their entirety, with a particular focus on 3 tracks, identified by the musicians as candidates for editing. Analysis of the resulting videos led to the addition of several more features including a control to turn on the phone's LED light in low-light conditions (the lighting was extremely low in both venues) and the addition of shots suitable for bands who used live projections. As one venue was very small, a number of nearly identical shots were captured by different operators at the same time. These duplicate shots violated the '30 degree' rule of film-making; where cuts from similar but not identical camera angles are read as a jarring jump-cut. The auto-director's logic was therefore changed to ensure that different operators would never receive the same shot request at the same time.

Figure 7. Difficult lighting was common at test events. Here, the stage lights had been turned off in favour of projections.

Two more shows were filmed, 1 month apart, with minor adjustments made to the auto-director logic and improvements made to the login system, both with 4-6 volunteers filming indie-rock bands in small bar venues. Once again, videos were edited from the resulting rushes and the musicians were interviewed. Further changes to the system included increased support for editors through minor revisions in formatting the metadata and a tightening of the auto-director's scheduling, reducing the length of shots that operators are asked to shoot.

EVALUATION

To date, Bootlegger has been deployed at 5 concerts by 4 bands to film over 40 tracks of which 6 have been edited into videos. After finishing Bootlegger's development, we subjected the footage and videos from later versions of the system to a multi-stage analysis to take in both straightforward dimensions relating to the quality of the system's results and more complex experiential factors concerning Bootleggers use.

We focussed first on the aesthetic qualities of footage captured at the test events, with particular reference to image quality, composition and coverage. As discussed, mobile devices often perform poorly compared to cameras with larger lenses or sensors in low-light, high contrast situations. In editing the trial clips into videos, each project was subjected to a conventional colour-grading process using Adobe Premiere's built in filters. Substantially more video noise was visible in the resulting films than might be expected from footage shot using professional cameras, however many of the musicians were enthusiastic about this quality. Although one musician commented that the slightly grainy image chimed better with his band's aesthetic than a more polished video might, this might not be appropriate for all musicians and represents a limitation of the system when used with older or low-specification phones. We anticipate however that as mobile phone cameras continue to improve, this problem may become less common.

Not only are mobile phones lighter than most professional cameras but their design necessitates holding them at arm's length in order to see the viewfinder. As concert-goers were unlikely to have access to any means of stabilising their devices, camera shake was a concern. Once again however, we were pleasantly surprised by how few shots had to be discarded due to excessive camera-shake. Several musicians actually highlighted camera-shake as a positive feature of their video.

"...you see these really slick, live videos that people have put together and while they can be very beautiful I don't necessarily feel any energy from the performance coming through". - Musician

In some concerts, especially those with moving lights or projections, the phone sometimes struggled to establish focus. This suggests that a manual or fixed focus setting might be appropriate in future versions of Bootlegger.

Bootlegger's shot descriptions and overlay images were designed to ensure coherency and quality in composition and visual style: however, they rely on users correctly interpreting them and having both the desire and ability to compose a similar shot. During recording, Bootlegger clips are tagged with information about the operator's role, the subject and the type of shot requested. To evaluate how closely users followed the shot allocations, we checked each clip manually to determine that its description matched its contents and noted the results.

We found that over 80% of shots were accurately tagged. Only one particular type of shot, *close-ups of musicians,* was often tagged incorrectly, as musicians struggled to capture them due to the phones' wide field of view. One audience member commented that,

"It was hard, you would have had to be right up in their face." - Audience Member

Overcoming this problem with current mobile phones is a challenge, as phone lenses are rarely interchangeable. At one concert we experimented with inexpensive clip-on lenses which allowed for tighter fields of view, at the expense of some image quality. Once again however, some newer mobile devices are now available with optical zoom which would eliminate this problem altogether.

In assessing how well the auto-director algorithm managed coverage of the events, we looked first at how many choices of subject it offered the editor at any moment. In the most recent test (see figure 9), with 5 cameras, the system was able to offer a minimum of 3 different subjects at any moment during a 40 minute live show, ranging from individual shots of musicians to detail shots and wide shots of the stage and audience. The differences in roles can be seen clearly in Figure 9: Users A and C were at the rear of the venue, while Users B and D were at the front. User E was in the middle, resulting in very different shot allocations. The shot allocations from one event (5 crew producing 107 shots) demonstrate how the auto-director requested shots clearly within the governing rules for the event *Subject Category (actual, requested), Lead: (49%, 50%), Musician: (40.1%, 40%), Audience: (3.7%,5%), Detail: (3.7%, 5%).*

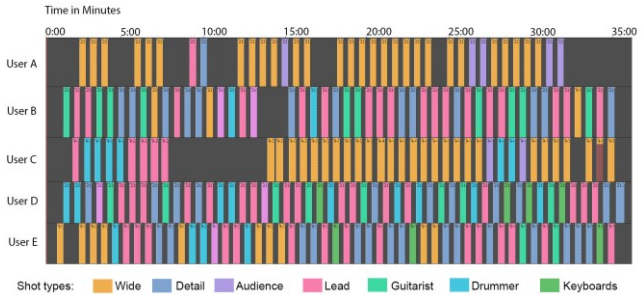

Figure 9. False-coloured shots captured during a 40 minute set laid out in a video editor.

As mobile phone recording at live events is a controversial activity, in developing Bootlegger we were particularly interested in how users felt about being co-opted into a camera crew, whether this increased or decreased their enjoyment of the event and whether they felt comfortable shooting for relatively long periods of time.

In general, all our volunteers reported that the experience was enjoyable and few reported feeling uncomfortable, even in approaching the band for close-ups. This was despite the extreme conditions of our tests, where users were asked to record for the whole duration of the set, rather than at certain moments. An exception to this was shooting members of the audience, which was distinctly unpopular with a number of users, partly because of social anxieties and partly because users felt that small audience numbers reflected badly on the artists.

"I felt self-conscious about the audience shot…I just didn't really do it, just because there was us filming and then a lot of people just looking miserable. I didn't want to film them."- Audience Member

To ameliorate this, early shots requesting close-ups of audience members were later removed leaving only a request to capture a brief wide shot of the audience. On one occasion, we did observe an operator apparently losing interest in shooting the event and beginning to exploring different features of the application however this only occurred in the final moments of one particular gig.

DISCUSSION

Bootlegger's development 'in the wild' and the discussions with artists surrounding it were productive, not just in building and testing the system but in providing a focus for discussion about the effect of technology on grass-roots music and the phenomenon of fan recording. Working with emerging musicians at small-scale shows was not however without its challenges. Often, the deciding factor in the success or failure of a video was not Bootlegger's performance but the aesthetics of the venue and stage and in some cases how well the musicians felt they had played. One edit which the research team thought was particularly successful was rejected by the artists immediately,

"I actually prefer the edit but we just made too many mistakes for us to use it." - Musician

Despite these challenges, the artists said that they would be able to use 4 out of 6 of the videos shot during the project, with only 2 early pieces rejected: one due to the artist's reservations about their own performance and one because of a lack of close shots.

A theme which recurred throughout our interactions with the artists was the importance of reciprocity and collaboration between artists, promoters and other figures in the music scene such as promoters and journalists. In a domain which generates little revenue, many of our musicians used publicity **a**nd recommendation as currency, often actively promoting other musicians' shows and releases over social media. When asked how often this promotion was reciprocated, one musician said,

"Always. I don't think we've ever had a band we've tweeted not retweet something of ours."- Musician

Bootlegger integrated well with this ethos and several of the musicians commented on particularly enjoying the collaborative aspect of the system, feeling grateful to their fans for taking the time to contribute to their work. One band asked that their friends be credited in the videos and that a Bootlegger logo be added to the end of the piece, wanting to acknowledge our support for their work.

Similarly, many of the volunteers at our deployments were either friends of the musicians or had already been to previous shows and were excited to be actively involved in supporting the musicians and contributing to their practice.

Many had suggestions for adding features to Bootlegger which supported this further, such as auto-generating credits or monitoring who had shot the most footage or captured the best shots.

One user commented that any discomfort he might have felt in using his phone camera at an event was greatly reduced by a sense of permission gained through contributing to the band's work. Having described his previous uses of camera phones at music events as *'for bragging rights'*, he stated that the experience of contributing to a greater project and working as part of an improvised team had felt far more positive and productive.

'There was a sense of belonging and I felt I was doing something important and those two things went together." -Audience Member

Several users commented that Bootlegger's continual requests for shots caused them some stress, leaving them feeling unsure whether they were allowed to leave the room, or stop recording. This may have been due to the extreme circumstances of the test events where fans shot an entire live set, rather than one or two tracks. A possible solution to this problem might be simply to include reassurances in Bootlegger's introduction that constant recording is not advised.

During discussions with musicians, we repeatedly asked whether they worried that fans were infringing their copyright through YouTube postings. In all cases the musicians enthusiastically replied in the negative, agreeing that if the video was a good document of the event, it represented a useful source of promotion.

POSSIBILITIES FOR OTHER DOMAINS

Bootlegger opens up a wealth of possibilities for exploring participatory camera orchestration and video production. Bootlegger's flexible architecture and event agnostic implementation suggest its possible use at other genres and types of live event, including sporting events, arts festivals, protests and rallies. Early prototypes are being deployed at real-world events with one version successfully trialled with over 30 volunteers at a UK half-marathon, the Great North Run. In parallel, alternative event templates and direction approaches are being developed to take into account differences in the format and structure of these events.

Some of these formats might well necessitate a more detailed approach to the way Bootlegger deals with the temporal structure of events. Currently, due to the often chaotic schedules prevalent in grass-roots music events, Bootlegger makes no attempt to distinguish between different parts of a concert set. In longer events (for example festivals or sports events taking place over several days), it may be necessary to incorporate automatic or manual switching between different phases to account for different types of subject becoming available at different times.

Bootlegger has the capability to orchestrate much large production teams, but we have yet to trial an event with large numbers of users and without briefing fans before the show. As Bootlegger is still in development, the study described here is relatively small scale and we have yet to determine how the approach will cope with more casual participants who might only take part in filming a small segment of the set. We speculate that the greater the number of participants the less likely this problem is to occur, however this hypothesis has yet to be tested.

We will continue to maintain the Bootlegger system, distributing and promoting the mobile application through Google's play store. This approach will enable us to deploy Bootlegger to a larger number of participants and bands and on a larger scale to investigate how participation in these contexts changes.

CONCLUSIONS

Using Bootlegger as both an automatic director and a basic camera tutor has enabled fans with little or no video experience to capture enough good-quality footage to provide an editor the material needed to create compelling videos. In our trials, Bootlegger performed well, effectively producing a variety of useable footage that our participant musicians have begun to use in their publicity material.

The musicians' enthusiasm for publicising their friends' and contributions and for promoting Bootlegger suggested that technologies that support community building for musicians can be valuable, potentially unlocking opportunities and resources in a domain where publicity and recommendation are valuable currency. It is of course possible that there may be unforeseen negative outcomes to this professionalization of user generated content. In designing Bootlegger we are attempting to harness the dynamism of fan footage, however it remains to be seen whether through instructing fans in cinematography, some of this dynamism might be lost. We suggest that supporting this type of activity using readily available and relatively inexpensive technology represents a useful and cost-effective way for musicians to promote themselves and each other. Moreover, using digital technology to 'professionalize' amateur media production can be both useful and rewarding for musicians and their fans.

Concerns over intellectual property and audience experience have led many established musicians to criticise or ban outright the use of mobile devices at music events. As this contrasts with the views of the emerging musicians we worked with, it is apparent that there is a point at which fan recording becomes detrimental to musicians' practices. We suggest that leveraging fan's desire to record their artist's shows and using systems like Bootlegger to ensure quality and control of IP might be a constructive solution to some of these issues.

Bootlegger has proved that orchestration of multiple cameras can be achieved through a relatively simple

synthesis of cinematography conventions and readily available technology. By combining elementary tuition in cinematography, a real-time directorial engine and a stream-lined system for logging and collecting footage, Bootlegger has demonstrated that mobile phones can be used to enable non-professional camera operators to contribute to a professional video workflow. Besides the potential benefit to musicians and other communities of practice described in this paper, these findings contribute to a growing body of knowledge around the integration of user-generated content with professional media practice. As the quality of mobile phone cameras continues to improve, we anticipate that systems like Bootlegger will increasingly blur the boundaries between professional and amateur media production.

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