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From the Lab to the OB Truck: Object-Based Broadcasting at the FA Cup in Wembley Stadium

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Figure 1: Ethnographic study at the OB truck of Wembley Stadium (top) and Kingsmeadow Stadium (bottom), UK

ABSTRACT

While traditional live-broadcasting is typically comprised of a handful of well-defined workflows, these become insufficient when targeting multiple screens and interactive companion devices on the viewer side. In this case study, we describe the development of an end-to-end system enabling immersive and interactive experiences using an object-based broadcasting approach. We detail the deployment of this system during the live broadcast of the FA Cup Final at Wembley Stadium in London in May 2018. We also describe the trials and interviews we ran in the run-up to this event, the infrastructure we used, the final software developed for controlling and rendering on-screen graphics

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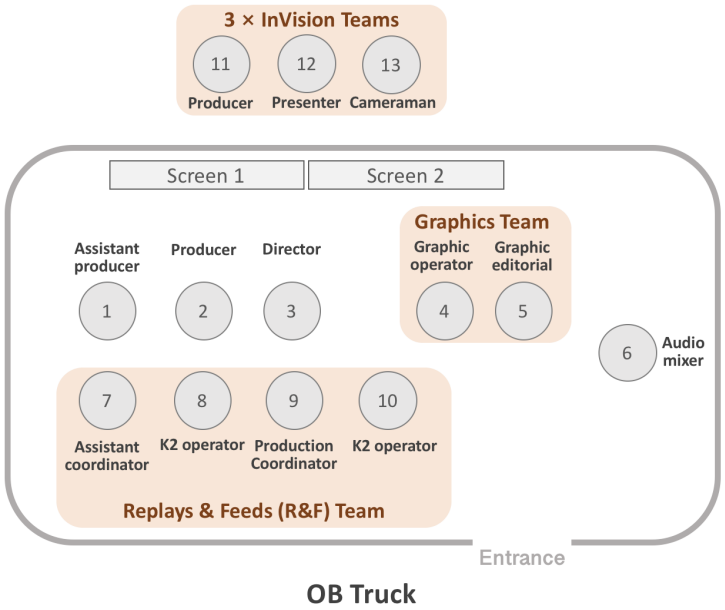

Figure 2: Layout of a typical OB truck used at a live sporting event

and the system for generating and configuring the live broadcast-objects. In this process, we learned about the workflows inside an OB truck during live productions through an ethnographic study and the challenges involved in running an object-based broadcast over the Internet, which we discuss alongside other gained insights.

CCS CONCEPTS

• **Human-centered computing** → **Field studies**; Graphical user interfaces; Empirical studies in HCI;

KEYWORDS

Field study; user interface design; networking; object-based broadcasting; second screens; immersive experiences

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INTRODUCTION

Live sport events are one of the mainstays of the television industry, since they bring the viewers close to the experience and enables them to enjoy the excitement of the event at home. The liveness is essential and cannot be reaplced by time-shifted on-demand viewing such as on Netflix [9]. However, due to the unpredictable nature of a live sport event, this is challenging for the production team, also because the event does not take place in a studio. Live outside broadcasts are a world of well-defined workflows which deal with time-critical tasks. The roles inside an outside broadcast (OB) truck at a live sport event are divided by task, to capture the event while minimizing delays and mistakes (Figure 1). Therefore, it is important that any software designed to supplement the workflow in an OB truck should be easy to operate, facilitate the collaboration within the production team and guarantee timely delivery of the live broadcast.

This case study presents the development and successful deployment of an end-to-end platform for interactive, immersive broadcasts at a live sports event. In particular, we detail the requirement gathering phase, the aspects of the system used during the broadcast, including *a graphics compositing application*, a so-called *Live Triggering* tool for inserting broadcast objects into live streams, the camera setup, real-time encoding of video feeds and content distribution over the Internet. We show the path from a rough first prototype to a complete multi-user platform with hardware integration. Finally,

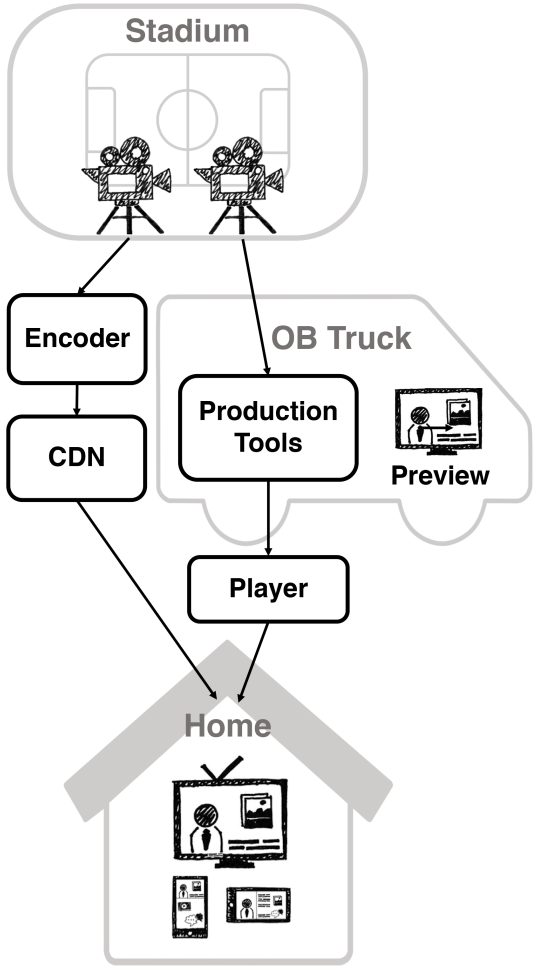

Figure 3: Production process for a live broadcast with our production platform. Content is recorded and edited on-premises and relayed to end-users via the Internet

we also present a series of trials and experiments that were completed along the way, culminating in the final deployment of the system at the FA Cup final at Wembley stadium in London in May 2018. There, the platform was used to support a test-broadcast of the football match, delivering the experience to a number of viewers at their homes.

At a big sports event such as this, an Outside Broadcasting (OB) truck is the most common unit for live broadcasting. With its mobility, OB trucks can access any location and work as a drive-in temporary production control center during live transmission, providing complete video and audio facilities (Figure 2). An OB truck typically has a wall of monitors shared by all of the staff in the truck. A video production switcher controlled by the director, an audio mixer, a team in charge of recording and playback decks and a team responsible for live graphics. It enables the production team to bring the TV audience an authentic visual representation of an event as it is happening [10]. OB trucks vary in size depending on the scale of coverage and the nature of the event. For a sport event, the coverage includes dozens of stationary cameras, a couple of handheld cameras, cameras on motorcycles to capture the main athletes and helicopters with cameras to shoot *long-shots* of the scene [7, 10]. Today, the production team in an OB truck orchestrate smoothly to deliver the same linear live program to all kinds of TV screens. The team typically follows a pre-scripted *running order document* that defines in detail where graphics, visual sources and sound come from and when they should be put *on-air* [7].

As users at home often have multiple devices at their disposal (e.g. smartphones and tablets) and these continue to be integrated into standard television, a challenge production teams are facing is to tailor the content of the TV program so that the content takes advantage of these additional devices and screens. Content on companion screens is customizable to provide the audience access to additional information next to the TV screen, thus enabling interactive and immersive TV viewing experiences [2, 4]. However, given the current workload of live broadcasting inside OB trucks, it is difficult to deliver additional versions of the program to multiple screens. New technologies are required for this purpose [1, 7]. One such technology is *object-based broadcasting* (OBB). It allows the content of a TV program to adapt to the requirements of different viewers on multiple screens, without requiring the production team to separately produce different versions of the program. The *object*, here, refers to different media assets or content objects that are used to make a TV program [1]. The OBB approach involves breaking down a program into separate objects, typically media content such as graphics, audio, video, subtitles or effects and augmenting it using metadata to describe how these objects can be assembled on multiple screens. It enables the creation of a flexible, personalized, and responsive program without increasing the production workload [1, 6]. A rough layout of the production process using our OBB system can be seen in Figure 3.

Figure 4: Timeline of the deployment of our end-to-end platform

PREPARATION

Previously, we reported successful groundwork for the design and development of a novel object-based broadcasting platform [6–8]. Our next objective was its deployment during a live event like the FA Cup Final 2018 in Wembley. To better understand the challenges of delivering such a trial at a live broadcast of a football match, the authors negotiated (via BT Sport) to be allowed to observe the current processes inside an OB truck during a live event. In particular, these events were observed:

- FA Community Shield match at Wembley Stadium on Sunday 6th August 2017, where access was granted only to one match truck. This event provided us with an overview of the director's role in creating the broadcast mix of video, graphics and commentary narrative for the match;
- Women's Super League match at Kingsmeadow Stadium on Thursday 1st February 2018, where access was granted to observe and record inside the OB truck. A number of GoPro cameras were used to capture the pre-broadcast preparation and live broadcast activity within the main gallery of the truck. These videos were composited into a synchronized quad view video along with the broadcast output.

The capacity afforded by Wembley Stadium in terms of connectivity, as well as physical gantry and production space, made it the preferred option as an event venue. In addition to the more ethnographic observations detailed above, the research team, working closely with the Chief Engineer and production team at BT Sport, was allowed to run live tests during two matches at Wembley on 22nd April 2018 (FA Cup Semi-Final) and on 12th May 2018 (National League Play-Off Final).

Such observations and tests resulted in a number of requirements, anticipating operational and technological risks. Such requirements included, for example, the creation of a number of documents such as the call sheet and the team sheet (for pre-populating the graphics with the correct player names one hour before the beginning of the match). The requirements also covered technological aspects, such as the pre-production of the assets, the development of the infrastructure to be deployed at the venue and in the cloud and the access to various data channels such as clean video data feeds. Finally, there were other operational guidelines for, for example, granting access to the researchers or colocating our mini OB truck in the OB Compound with the other broadcasters. The following subsections will detail the different preparation steps before the official match day.

Graphics

Object-based broadcasting provides user-level personalization and it thus requires all broadcast graphics (non-video visualizations overlaid on top of the video) to be composited on the client device. This is a major shift from traditional broadcasts, where all graphics are overlaid and burnt into the transmission signal at the OB truck. This requires new and more flexible ways to author graphics. Experience from previous trials, where we took on a quite developer-centric approach to coding such

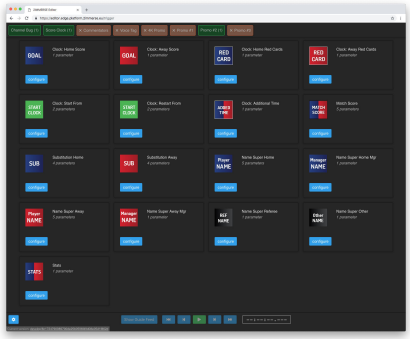

Figure 5: Triggering tool in operation inside a web browser

Figure 6: Trigger launcher (top) and hardware device *StreamDeck* (bottom) for operating it more conveniently

graphics in HTML and JavaScript, showed that the process was cumbersome and time-consuming. The design of these graphic elements and animations are valuable assets for a broadcaster and are thoroughly defined and specified down to pixel perfection. For the FA Cup Final we wanted to try out a more designer-friendly approach by utilizing an existing broadcast WYSIWYG graphics authoring tool. The tool we choose was *ChyronHego Prime*. Using the ChyronHego Prime scene description file format, the researchers created a specialized renderer for object-based broadcasting which can execute Prime-authored graphics on the client devices in real time. At the FA Cup Final, *ChyronHego Prime* was also used for creating the traditional broadcast graphics (4K HDR), so we were able to re-use assets created for the broadcast graphics in our object-based broadcasting workflow as well.

Production Tool

Previous work of the team resulted in a novel model and workflow for production tools for object-based broadcasting [5, 7]. The tools were originally intended to cover MotoGP races, but we had the intuition that they could be adapted for other sports as well. We thus arranged a number of conversations with professionals working on TV sports broadcasts, asking them to detail their experiences and workflows. We also carefully studied the recordings from the OB truck at the FA Women's Super League game. Drawing upon these observations, we concluded that our existing platform was a good starting point, but required some modifications. First, all controls needed to be easy to manipulate and target. Second, the person preparing content for, e.g. replay clips is not the same as the person who decides when and if the content is actually broadcast. The former task is shared by several people, whereas the latter is usually performed by either the director or a vision mixer. Finally, we learned that trucks are equipped with special-purpose devices, providing direct access to specific functions.

Based on the requirements, we designed a new version of our live triggering tool, diving it into two sub-tasks, each one targeted at a different professional (Figure 5). The first tool, called *Triggering Tool* allows to prepare media, such as replay clips, or inserting on-screen labels and queueing them for the director to launch. The second one, called *Trigger Launcher*, intended for the director, can be used for launching these events, i.e. inserting them into the broadcast. For the second one, we were able to integrate support for *StreamDeck*, a hardware device intended for video-game streamers. The device is equipped with 15 buttons, where each button is backed by a 72×72 pixel LCD screen, plugged into the computer via USB (Figure 6). This enabled us to map the events rendered in the trigger launcher onto the buttons, allowing the user to conveniently launch and modify events quickly from this console instead of having to use the mouse and click the corresponding button on the computer screen.

OBJECT-BASED BROADCASTING DURING FA CUP FINAL

After the preparation work described in the previous section, the research team was (almost) ready to bring a unique football experience of the FA Cup Final at Wembley Stadium to people's homes. The

Figure 7: Experience at home as viewed by an end user: television screen (top), tablet (middle) and user-customizable screen configurations for companion screen (bottom)

football experience was to be a unique, object-based broadcast, since a multitude of media objects could be assembled in a personalized manner and rendered on different screens at home: a single primary shared screen (main TV) coupled with a companion device such as a tablet (Figure 7).

The deployment at Wembley Stadium was centered around our own OB vehicle, a Mercedes Sprinter van fitted with two small work areas and basic services such as power, cable routing, air conditioning and lighting. This vehicle was essential as a space to safely host and operate the additional components required for object-based broadcasting. The vehicle was provided with assistance from BT Sport, who also provided essential access to the necessary infrastructure and live feeds and provided a listen-only feed of the Match Director's talkback channel within the vehicle. This enabled the team to hear and follow the majority of vision and graphics cues given by the director throughout each match and thus test the object-based production tools in a representative way. The following paragraphs detail the different components deployed during the day of the match.

Live Camera Feeds. The project team requested access to a range of live camera feeds. We had access to the clean and dirty (Match Director's output) broadcast feeds, the main camera-wide shot, the manager cameras, the team benches, cameras behind each goal and the Spider cam. Each camera feed was provided in HD-SDI format through a separate coaxial cable routed from the BT Sport production truck to the vehicle.

Live Encoding. Two live streaming encoders were loaned for the duration of the tests with assistance from BT Sport. Each encoder was capable of live encoding a multi-layer DASH representation of 8 HD-SDI input streams. Once encoded, the DASH segments were uploaded to our CDN origin server, from where they could be consumed by the client applications. Given that the FA Cup Final match was simultaneously broadcast free-to-air in the UK, it was agreed that stream encryption need not be used, but instead access control was applied to the CDN so that client apps were required to authenticate before they could download the stream.

Internet Uplink. Using additional live encoders also necessitated providing Internet uplink capacity dedicated to the OB vehicle. At least 100Mbps was required to upload the 3-layer MPEG-DASH representation for 8 distinct live streams, while providing headroom for audio streams and signaling.

Triggering Interface. One half of the OB vehicle was dedicated to live triggering of object-based production graphics using the production tools described above. The tools ran on a laptop with the addition of an Elgato Streamdeck programmable keypad. The production tools communicated with our platform services, which were hosted off-site inside an Amazon Web Services environment. The production tools were modified as well to enable the preview client to display the live feed from the capture device within the primary video player component, rather than opening the delayed MPEG-DASH stream from the CDN origin server.

Figure 8: The setup of the system in the OB truck at the stadium

Tracking. A headless camera tracking system (ChyronHego Virtual Placement) was set up independently of the live production tools in one half of the vehicle during the FA Cup Final event. Its purpose was to collect the main camera pose parameters during the game. These parameters are crucial for creating augmented graphics (graphics that blend into video as if it was part of the three-dimensional scene). Traditionally, while burnt into the broadcast feed, these systems are used for adding billboards, rendering team logos on the pitch, visualizing information such as distance to goal on free-kicks, show offside lines or player names. 2-IMMERSE researchers are using the captured data as research material to explore augmented graphics rendered in the client. At the same venue we also captured player tracking data from the ChyronHego TRACAB player tracking system, which can determine the location of all players in real-time. Having synchronized data sets with video, camera tracking and player tracking is valuable for future research in the object-based broadcasting domain.

2-IMMERSE Platform. The 2-IMMERSE platform [5, 6] was the most significant off-site component, playing a vital role in the delivery of the end-to-end live tests. As with all 2-IMMERSE presentations (dubbed *Distributed Media Applications*), distinct services were responsible for orchestrating the viewer experience on end-user devices by managing layouts and and timeline sequence of on-screen objects. Additionally, for these tests it was also necessary to orchestrate live previews for the OB truck. Another crucial extension to the platform was the ability for timeline updates which were created by the Live Triggering Tool to be automatically propagated to the active timelines of every client context playing back the match, while accounting for the fact that off-site viewers' timelines might be delayed by up to a minute due to large buffers resulting from the MPEG-DASH live streaming configuration.

DISCUSSION

New challenges for the industry. During the project (Figure 4), we successfully bridged the gap between lab research and key players in the production chain (e.g. BT Sports, MoovTV), motivating them to think about use cases or tools taking advantage of OBB. As noted by Bentley et.al. [3], the ethnographic-style field study takes new concepts to real users in early development stages, quickly illuminating potential bottlenecks and challenges. In our trial, the first challenge was to smooth the graphics creation workflow in this time-critical environment. To do so, we used an existing authoring tool (ChyronHego Prime) with a graphical interface with an XML-based storage format, enabling a *designer* to create graphics without *developer* support. The second challenge addressed is the usability of the live OBB production tool. A new version of this tool was separated into two parts. One part is used to prepare and queue media assets by an assistant of the director, the other part is for the director to launch the media assets from this queue. The new version is expected to reduce the workload for the director and result in a smoother workflow. The third challenge we addressed was the live delivery of triggered objects from the OB truck to the homes of viewers in a timely manner.

Impact on the industry. Based on the collected assets (Figure 8) during the live event, we developed a more complete as-live multiscreen FA Cup demonstration, showing how our tools can be used to edit broadcasts in an OBB approach. It showed how viewers can personalize their experiences through companion screens in home contexts. The demonstration was successfully presented at the *Future Zone* of IBC[1] (Figure 9), the most influential media exhibition in Europe. It targeted a wide audience, including key stakeholders from broadcasting and academia, all who believed '*OBB is the future*'.

[1] *International Broadcast Convention* https://www.ibc.org

Figure 9: Presenting the project at IBC 2018 in Amsterdam

FUTURE WORK & CONCLUSION

To help integrate the OBB approach into existing production workflows, the next step is to develop a pre-production tool with a graphical interface, to allow people without programming skills to author multiscreen content. The pre-production tool aims to reduce the workload of live broadcasting by enabling producers to create a rough storyboard of the broadcast and drop in pre-produced content ahead of time [7]. The prototype of the pre-production tool has been tested by a group of TV professionals in December 2018 by means of a structured interview. The live trial at the 2018 FA Cup Final was a milestone to help the OBB approach to make an impact. Through observing two live football matches, the content acquisition and distribution was tested and the live production tools were refined to be able to trigger all graphics during the match. Our objective of authoring a live end-to-end OBB experience and testing the reach and scalability of our solution was achieved and can hopefully be used to augment production workflows in future sporting events.

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