Developments in Automated Tapeless Production for Multi-Camera Programmes

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Abstract

The BBC R&D Ingex system is a tapeless recording system for multi-camera television production which combines high quality multi-channel recording with a range of automation features to speed up some of the time-consuming tasks in current television workflows.

A suite of software components has been developed to provide an integrated and automated system, providing a range of benefits to production and post-production. Recent additions include capture of vision mixer cut decisions and web browser based material review.

Based on open source software and commodity IT components, the system has been used for several BBC productions and is now becoming available through third party service providers.

This paper presents an overview of the current Ingex system, describes recent development of the automation features, and provides an outline of how they are used in BBC productions such as EastEnders, Dragons' Den, The Bottom Line and BBC HD Jazz Shorts.

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INTRODUCTION
The Ingex system is a tapeless recording system for multi-camera television production which provides multi-channel recording and a range of automation features to help the production team work effectively.

The system was initially developed in 2005 and used for the production of the BBC children's programme BAMZOOKI [1] [2]. Since then, the system has been further developed [3] for use in a broader range of productions, each with their own particular requirements. The focus has been on providing useful automation tools, built around the core recording system, which enable the different production teams to work more effectively and reduce laborious non-creative tasks of various kinds.

OVERVIEW OF THE INGEX SYSTEM
The key components of the system are shown in Figure 1. The heart of the system is the Ingex recorder, which is a direct-to-disk recorder consisting of a high-end multi-core PC, multiple SDI/HD-SDI capture cards and the Ingex software. Under the control of a user interface in a production gallery, Ingex recorders are used to capture the studio feeds at full quality, encode them in real-time to the required production formats and store the results in standard file formats such as MXF or Quicktime. With advances in processing power, the Ingex software is able to simultaneously capture and encode four channels on each recorder, and store the results in the required full-resolution and offline formats for editing. Each unit is typically built with several terabytes of local storage to allow self-contained operation for several days of recording.

The Ingex suite of software includes other components to provide an integrated and automated system, providing benefits to production and post-production teams.

- Custom user interfaces for operation from a production gallery (see Figure 3)
- Immediate playback of recordings to the gallery, in full quality or as a “quad split” view.
- Logging of descriptions, comments and cue points against recorded material.
- Multicast streaming of studio feeds over an IP network, allowing a wider range of production staff to see the action.
- Recording to a wide range of production formats including uncompressed, DVCPro50, IMX50, Avid JPEG 2:1/10:1/20:1, DVCProHD and SMPTE VC3 (DNxHD), and to multiple formats in parallel. By recording directly into the required full resolution production format, the small losses in picture quality associated with an intermediate tape format are avoided.
- Automated transfer of recordings to remote destinations, for example to a network file server or portable hard drive.
The system also provides benefits after the recording and into post-production, using the components shown in Figure 2. In particular:

- Browser-based review of recordings, for example at remote locations, and viewing on portable tablet devices.
- Seamless transfer of recordings directly into post-production, eliminating time-consuming digitising from tape. By using standard MXF “OP Atom” files the material can be used directly within Avid editing systems without further processing.
- Clips automatically presented in multi-camera groups in the edit suite, eliminating the need to set these up manually.
- Metadata from the production (shot descriptions, comments and cue points) are transferred into the editor with the recordings. Using standard AAF files, this is a drag-and-drop operation.
- “Director’s Cut” capture of the vision mixer cut decisions and automatic conversion into a rough-cut edit timeline in post-production, linked back to the isolated camera recordings (ISOs). This allows the editor to start quickly with a rough-cut as if from the mixer out, while also being able to immediately trim any of the cuts.
- Compatible with tape-based working. Allows file-based offline edit and conform from tape, if required.
Figure 2 – Ingex components used after recording for review & transfer to post-production
Figure 3 – Ingex production gallery interfaces and recorder control
DEVELOPMENTS IN AUTOMATION FEATURES

Capture of studio vision mixer decisions

The system's director's cut feature allows vision mixer cut decisions in a multi-camera studio environment to be recorded in real time using either a quad-split interactive player or as serial data from a suitable video switcher. The mixer cut decisions can then be brought into post-production as a rough-cut of the programme, linked back to the individual camera sources, speeding up the initial assembly of material in the edit suite.

This feature has been extended to operate by analysis of the vision mixer video output, applying computer vision algorithms to a frame matching technique. This has the advantage that it can be applied to any kind of vision mixer or switcher, without having to interface to a specific control output indicating which source has been selected.

The technique is outlined in Figure 4 and consists of the following steps:

- For each feed going into an Ingex recorder, an image signature is calculated for each frame. This is done for the multiple camera source feeds and one mixer out feed.
- The signatures from each recorder in the system are collected together and compared.
- For each frame, a decision is made as to which camera source matches the mixer output (if any), and recorded as cut metadata with the matching timecode.

![Figure 4 – Deriving mixer cut metadata using image analysis](image)

By basing the frame comparison on image signatures, it is not necessary for all the feeds to be present in a single Ingex recorder for direct pixel comparison, thereby allowing the image comparison method to scale up to large numbers of feeds. Furthermore, the design of the signature and method of comparison can allow small distortions or spatial shifts of the mixer output compared to the camera sources to be ignored, which is operationally desirable.

The signature consists of ten values, as follows:

- Average luminance over a frame
- Average absolute value of nine 2D 3x3 texture measures (Kenneth Laws’ texture measures: average L3, edginess E3 and spottiness S3) [4]

An example of the texture measures (prior to averaging) is shown in Figure 5 (left to right: average, edginess, spottiness; top to bottom: average, edginess, spottiness).
Browser-based review of recordings

The ability to review recordings easily is one of the advantages of tapeless working, whether during the shoot or afterwards. In the gallery, for example, the production team can check that a recording is satisfactory before moving on, or check an editorial or continuity issue immediately to prevent a mistake being made. Beyond the gallery, access to production rushes (and associated metadata) in a browser over a wide area network allows the production team, wherever they are located, to review current recordings and know precisely what is available, add annotations, research relevant material in earlier programmes, plan for the edit, and visualise rough assemblies of material.

In order to investigate the usefulness of such review facilities, a web based material review facility has been added as an optional component in the Ingex system, to support both browser-based access to recordings over a wide area network and access from portable tablet devices (see Figure 2 – web & portable review workflows).
The implementation automatically transcodes incoming MXF files from the Ingex recorder to Flash and QuickTime video proxies, suitable for web streaming, as shown in Figure 6. If Director’s Cut metadata is available, a video proxy visualising the material as cut is also created. Driven by the production material database, a comprehensive web-based review system is provided.

![Figure 6 – Video proxy generation for browser-based review](image)

The current browser-based system is shown in Figure 7. The facilities available are as follows:

- User authentication & basic security
- Hierarchical browse view of recordings ordered by project, date & timecode
- Playback of camera isolated recordings (ISOs) and quad-split display of multiple cameras. Director’s cut metadata is used to highlight the selected camera in the quad-split display, and provide a visualisation of the material as cut
- Metadata from the production (shot descriptions, comments and cue points) is displayed, and highlighted on the player timeline

The potential of portable tablet devices (such as iPad and Android tablets) as a means to review, mark-up, plan and generally collaborate is an active area of current work. Figure 8 shows a simple material view running on an iPad.
**Material Browser**

**Figure 7 – Browser-based review of recordings**

**Figure 8 – Simplified review page on an iPad**
PRODUCTION CASE STUDIES

Television programmes have wide ranging and varied production requirements. Four different BBC productions that have started to use an Ingex tapeless workflow are reviewed.

EastEnders

EastEnders is a popular serial drama with four episodes a week. It is produced in blocks, with four episodes made concurrently. The programme is recorded at Elstree Studios using two studio areas and an outside lot, and post-production is on site. EastEnders is scripted meaning the production team work through a pre-planned set of scenes and dialogue.

The Ingex workflow is as follows:

- Ingex records all camera feeds & vision mixer out, using MXF 10:1 JPEG offline and 2:1 JPEG online formats
- Basic logging of shots is available in the recording controller
- Offline and online recordings are automatically transferred to the post-production network file server where they are used in the Avid edit suites
- Playback of recordings to the studio is provided, including material and rough-cuts from post-production
- Director’s cut feature is used to capture vision mixer cuts and create a rough-cut edit timeline in post-production, linked back to ISO camera recordings

Dragons’ Den

Dragons’ Den is an entertainment programme, in which entrepreneurs pitch business ideas to wealthy would-be backers, in the hope of getting them to provide funding. The programme is recorded at Pinewood Studios during a two month period using two studio areas. The post-production follows on at Sumners post-production in Manchester. As the outcomes are not known in advance, good logging and review facilities are valuable to mark and find the key moments of each pitch. Being shot in a film studio, many television facilities need to be specifically provided for the production. Since 2009, the programme has been made in HD.

The Ingex workflow is as follows:

- Ingex records all camera feeds & vision mixer out, using MXF 10:1 JPEG offline and 120 Mbit/s VC3 (DNxHD) online formats
- Basic logging of shots is available in the recording controller
- Offline and online recordings are automatically transferred to a portable hard drive and then physically transported to the post-production facility for editing on Avid suites

During tests on the 2009 series, a network link from Pinewood Studios to Sumners in Manchester was used to deliver the SD offline and HD online studio rushes automatically from the Ingex recorders to a server at Sumners. This worked well, achieving 70 MByte/s total throughput with 18 ms round trip time (RTT) latency, and little packet loss.

Also, the ability to view live studio feeds using the multicast streaming viewer facility proved useful to the wider production team, enabling the lighting director to get a better view of the camera outputs and helping the production assistants follow the progress in the studio.

The Bottom Line

The Bottom Line is a weekly radio discussion programme, which is also recorded for television, in which Evan Davis discusses topical business issues with three guests. The programme is recorded at Broadcasting House in a radio studio, with hired-in television production equipment brought in each week. The key features of this programme are fast turnaround and delivering multiple
versions. The radio edit occurs on the day of the recording, and the television edit is done on the following day at Clear Cut Pictures in Hammersmith.

The Ingex workflow is as follows:

- Ingex records all camera feeds & vision mixer out, using MXF 2:1 JPEG online format for the television edit
- mp3 audio file uploaded to external FTP site for retrieval by an external transcriber
- Basic logging of shots is available in the recording controller
- Ingex records additional web-only “My Bottom Line” segment, using MPEG-2 programme stream format. Recordings transferred to portable USB stick or via BBC IT network
- Ingex records additional material for the Open University related to the topics of the programme, using MPEG-2 programme stream format. Recordings transferred to external FTP site for retrieval by the Open University.
- Programme stills selected from recordings, and transferred as JPEG images to portable USB stick or via BBC IT network
- Online recordings are automatically transferred to a portable hard drive and then physically transported to the post-production facility for editing on Avid suites
- Director’s cut feature (with the image based matching) is used to capture vision mixer cuts and create a rough-cut edit timeline in post-production, linked back to ISO camera recordings
- Browser-based review of the programmes in each series used for assembling the “best of” compilation

**Jazz Shorts**

Jazz Shorts was a BBC HD pilot made by Sixth Stage in Clapham, consisting of three programmes presenting an intimate and immersive HD experience of a modern jazz concert.

The Ingex workflow was as follows:

- Ingex recorded four camera feeds (with 32 audio channels) using QuickTime DVCProHD online format. Small lightweight cameras with HD-SDI outputs cabled up to Ingex allowed intimate and up close camera positions.
- Basic logging of shots was available in the recording controller
- Online recordings were automatically transferred to a portable hard drive and then physically transported to the post-production facility for editing and grading on Apple Final Cut Pro suites
- Director’s cut feature is used to capture vision mixer cuts and create a rough-cut edit timeline in post-production, using Apple XML file for Final Cut Pro

**SYSTEM AVAILABILITY**

The software components for Ingex are made available as open source software [5], allowing a wider industry take up of the system. Several production organisations have built their own systems and used them successfully in trials & individual projects, motivated by the low cost of the system, its unique open nature which allows the system to be adapted for new requirements and the creative dividend from a more fluid workflow.
The system is now becoming available through third party service providers, either based completely on the existing open source or using parts of the technology within different applications.

To assist the transfer of Ingex technology to service providers, BBC R&D has established Ingex Solutions (a unit within BBC R&D) with the objective of providing support and coordination to companies providing Ingex systems [6].

CONCLUSIONS

The Ingex system provides a range of integrated and automated features built around the core tapeless recording technology. The main benefits to production teams are the ability to produce a wide range of file formats simultaneously, provide access to recording logs, automatic transfer of recordings to remote destinations and file compatibility with common editing systems.

Recent work to capture vision mixer cut decisions for an automatic rough-cut in post-production and to develop browser-based material review facilities have been tested with productions and found to be a useful addition.

After several years of development and trials in a range of BBC productions to validate the different features and system reliability, Ingex is now becoming more widely available through third party service providers and Ingex Solutions.

REFERENCES

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