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To test this approach in practice, BBC R&D has developed such a system and this was used during October 2005 for the production of the latest series of the BBC children's programme 'BAMZOOKi'.

Encouraging results from that production work have resulted in further enhancements to the suite of software, which now includes a media server configuration capable of supporting different editing systems from a common set of media files. Much of the software developed is now available as open source.

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ABSTRACT

The falling cost and increasing performance of PC hardware means that tapeless production using commodity equipment is now realistic. Controlling this with an automated system for logging 'takes' in the studio gallery provides an efficient workflow from studio into post-production with considerable savings in time and costs.

To test this approach in practice, BBC R&D has developed such a system and this was used during October 2005 for the production of the latest series of the BBC children's programme 'BAMZOOKi'.

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INTRODUCTION

Pen and paper is still the most common method for capturing metadata during TV production. Although there are systems for capturing metadata electronically, they tend to focus on a workflow where material is recorded first and then reviewed at some later time to create metadata ('logged'). In studio production, the logging is generally done as the material is being recorded and use of pen and paper is almost universal. When it is time to edit the programme in post-production, a great many timecodes have to be entered from the paper notes in order to select the required content.

The first stage of our work was to develop a system which would avoid the laborious re-entry of handwritten metadata into the edit system. Following on from this, it was clear that combining this with tapeless production, particularly using low-cost commodity PC hardware, would provide very significant advantages both in the efficiency of the workflow and equipment costs.

For the second stage of this work, we therefore linked tapeless recording to the logging so that the required audio/video content could be moved directly into the edit system, at full broadcast quality. This also provided fully indexed browse copies of the studio recordings on DVD and web pages, opening new possibilities for the way in which the production team can work with their content.

To prove this technology in a real production environment, we worked with the BBC programme 'BAMZOOKi', a children's game show, during the recording of their last two series in October of 2004 and 2005. Since then, we have further enhanced the interoperability with post production edit systems through the use of open standards and low-cost server implementations.

TYPICAL STUDIO PRODUCTION WORKFLOW

A typical recording in a television studio is planned in detail to make efficient use of the facilities and staff. There will be a script for the programme and from this a recording order will be produced. Some items in the script may be pre-recorded (e.g. VT insert) whilst others may have to be recorded in multiple passes (e.g. normal and close-up passes).

For each item, the Director will cue the action and a 'take' will be recorded. As each take is recorded, the Production Assistant (PA) will note the details including start and end timecodes, whether the take is 'good' (i.e. useful in the edit) or not, and any comments. If the take isn't fully satisfactory, another take will be recorded, and so on.

During each take, in addition to the vision-mixed output ('Main'), a small number of isolated ('Iso') camera outputs may also be recorded, as these may be needed during editing to provide alternative views of the action.

As well as the broadcast-quality recordings, a lower quality copy (VHS or DVD) of a composite view (e.g. quad-split) combining the Main and Iso channels is usually recorded with in-vision timecode. The PA might use this for checking continuity and the Director or Producer might use it to prepare for the edit.

After the studio recordings, the workflow moves on to post-production. Wanted material (e.g. good takes) is ingested into the non-linear edit system. The initial edit is usually done at 'offline' (lower) quality and then followed by a 'conform' when the material for the edited programme is re-ingested at 'online' (broadcast) quality and the same edits applied. Working at lower quality has the advantage that it is less demanding on processing and storage requirements and so can be faster. Alternatively, the entire edit can be done at online quality and this was the method chosen for the most recent series of BAMZOOKi.

To complete the programme, it may go through separate finishing and audio ('dub') post-production steps.

AUTOMATED STUDIO PRODUCTION WORKFLOW

The aim of this work is to bring automation to as much of the production process outlined above as possible. Figure 1 illustrates the key areas that we are addressing, from studio recording to post-production. The workflow starts at the left hand side with the live sources from the studio and, in parallel, the logging of those sources as they are recorded. The video

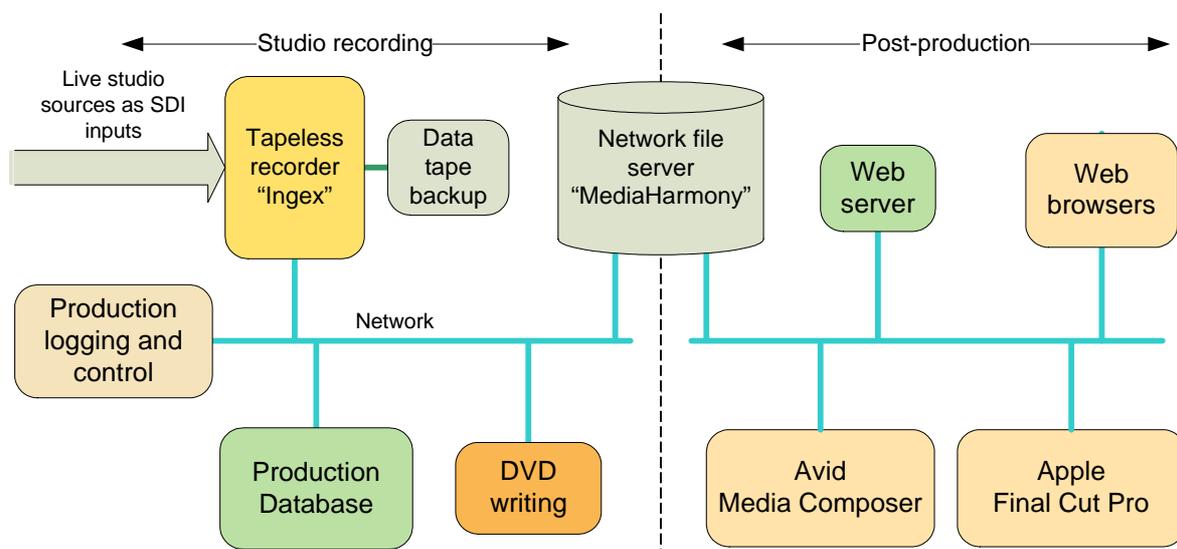


Figure 1 - Key elements of the automated tapeless production system

and audio feeds themselves are recorded on the disc-based recorder 'Ingex' (described later) which simultaneously produces online and offline quality files, as required, for post-production. Control of the recorder can be either integrated into the logging software or from a separate control application. In either case, the logging software will update the production database as 'takes' are recorded and at the appropriate moment, the PA can 'publish' the material to make it available downstream, for review or editing.

The network file server 'MediaHarmony' (also described later) stores the recorded content in appropriate formats to make it available to any of the post-production edit systems.

Whilst these processes are underway, the log details and content are also processed to make them available on DVD, web-pages or portable viewing devices.

It should be noted that automation is paramount here. The entire flow of log information and recorded content is carried out in the background without any user intervention, once each 'take' has been published from within the logging system by the PA.

PRODUCTION USE

Objectives

During the development of the ideas described here, we have been able to work with the production team for the BBC Children's programme BAMZOOKi for their second and third series. Testing fell into two parts: during the first phase, in October 2004, the objective was to eliminate the time-consuming and error-prone manual entry of timecode data during post-production, and we therefore concentrated on the logging aspects of the workflow. The second phase, in October 2005, additionally employed tapeless recording to eliminate ingest from tape and to provide electronic review copies of each day's recordings.

The various elements that we provided for the production team are described in the following sections.

Logging

The logging system runs on a PC with a small keypad and an external timecode interface fed with studio timecode. It is installed in the studio control room, as shown in Figure 2, and is used by the PA, who generally sits next to the Director.

The logger needed to be easy to use and compatible with conventional working practice. In the same way that the PA would usually use a stopwatch to time a take, the main interaction with the electronic system is to press a button on the keypad at the start and end of each take. As with a stopwatch, the computer display shows the duration, but it also shows the start and stop timecodes.

Other buttons allow the take to be marked as 'good' or 'no good'. Comments about the take can be typed in using the main computer keyboard.

The logging software reads in a script or recording order and presents a list of items which the user can step through to select the one for which a take is about to be recorded. Further items can be added to the list as needed. Names of sources being recorded (Main, Iso1 etc.)

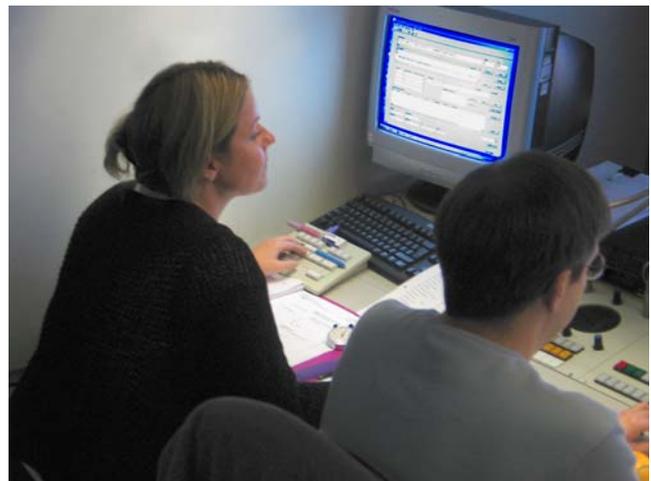


Figure 2 – Logging in the studio gallery

can be entered along with spool numbers of the relevant tapes.

As well as saving log information in a file, the logger can produce a printout in a similar format to the conventional handwritten log sheet.

In the trials, the electronic system was operated in parallel with pen and paper. That, in itself, is a testament to its ease of use. The PA also greatly appreciated the fact that timecodes were frozen on the logger screen for her to write down, instead of having to be copied from a continuously running display on a video monitor.

For the later, tapeless, setup, the logger appeared much the same to the PA but now, for each take, it automatically started and stopped the recording system via a network connection. Details of all recorded files were passed back to the logger and stored with the log data. This data was 'published' regularly as new takes were stored so that processing of recordings could take place automatically.

Tapeless recording

The recording system, 'Ingex', is a PC with multiple SDI video I/O cards. It captures several feeds of video and audio, processes them into a range of different formats, and stores the results on disc. In the configuration used for BAMZOOKi, the video was stored in both uncompressed and MPEG-2 formats. As described below, the uncompressed version was later processed to suitable post-production formats and the MPEG-2 version was used for review copies on DVD.

One of the key features of the recording system is that it automatically includes pre- and post-record handles. Each audio/video input is continuously passed through a 30-second long buffer so that when the beginning of a take is marked, content from before that time is still available in the buffer. We configured the system so that recording effectively started 5 seconds before the PA pressed the start button. The recording also continued for a few seconds after the end of a take was marked.

The hardware consisted of commodity IT components with a total cost of approximately €20000, the most expensive components being the video I/O cards. The software was developed in-house and runs under the GNU/Linux operating system. It has been made available as open source by the BBC (1). A more detailed description of the recorder can be found in Tudor and Cunningham (2).

Review

A VHS tape or DVD of a day's recording in a studio is usually made for review purposes. Conventionally, this would simply be one long recording with timecode in vision but with the inevitable drawback that locating the required material later can be time-consuming.

The combination of electronic logging and recording allows us to provide review copies in various forms, each with a detailed index. So far, we have experimented with three approaches to this: DVDs, web pages and portable devices, such as video iPods. For each of these, our automated process produces the necessary encoded content and menus as each new take is published by the logging system.

DVD creation

In order to avoid using an excessive number of DVDs, only takes logged as 'good' are included on the discs and navigation amongst these clips is provided by two levels of menu using details from the logging system. This allows any scene and take to be selected and, within that, the Main, Iso or a quad-split of all sources, can be viewed.

As a further aid to clip identification, log details such as scene number, scene title, take number and comments are encoded into the MPEG streams as 'forced' subtitles, so that, when any clip is replayed, these appear over the picture as though they were 'burnt-in'.

After the DVD authoring stage has finished, the VIDEO_TS directory for the DVD is ready for burning onto blank DVDs but the discs themselves are not written at this point. Instead, the authoring process continues to repeat automatically, updating the DVD files in the background as necessary, each time new takes are made available. In this way, when the discs themselves are required, typically for the Director to take away at the end of the day, only the writing to the blank discs has to be carried out, thereby saving significant time.

Although the use of DVDs proved to be very effective as a way of providing a review facility, the limits imposed by the DVD specification meant that, generally, three discs were needed for the rushes from each half day's shooting. Even transferring only 'good' takes to the DVDs, the limit of 40 buttons per menu and 99 video clips per disc were soon reached. An additional drawback is that most DVD players do not offer accurate jog controls and this makes it awkward to review the content in detail in order to determine edit points, etc. Despite these limitations, having all the rushes on DVDs does offer advantages, particularly by giving a 'reference' copy of the content which includes all the details from the log.

Web-page

In a similar way to the process used for DVD creation, once new content is published by the logging system, background processes update web-pages containing the log details and browse quality versions of the recordings, as shown in Figure 3. As storage capacity is less of an issue with the web-page, all the takes, whether marked 'good' or 'no good', are stored, so that all recorded clips can be reviewed.

Sequence 14-16: COUNTDOWN, 1ST CONTEST & WINNER ANNOUNCED

Take	Timecode	Good/NG	Description	Main	Iso 1
1	16:46:07:07 - 16:46:20:04	NG	NG - CHILD DID NOT SPEAK	BRD251641	BRD251642
2	16:46:51:19 - 16:48:08:21	Good	GOOD UNTIL JAKE FLUFF IN OUTRO	BRD251641	BRD251642

As well as using the web-pages to review the content, an enhanced version, currently under development, also enables the log details to be edited at the same time. This will provide a convenient way in which away the log details can later be expanded or corrected, away from the pressures of the production gallery.

Portable viewing devices

A further background process encodes and then transfers the content for review on hand-held media replay devices such as an Archos, video iPod or Tablet PC. These offer the advantage of being entirely self-contained but the smaller screen size means that editorial decisions can be more difficult.

Processing the media files

As the BAMZOOKi programme was to be edited using Avid Media Composer, a key issue was how our recorded content, recorded in uncompressed format by the Ingex system, would be transferred seamlessly into this edit system.

Material Exchange Format (MXF) is becoming widely supported and is standardised by SMPTE (3). Operational Pattern Atom (OP-Atom) is particularly suitable for editing as each audio and video track is stored in a separate file. Avid Media Composer supports MXF OP-Atom for native media files and by processing our recordings to this format, we made the content directly available, without the need for any additional import step.

Within the MXF wrapper, various forms of video encoding are supported by Avid, such as uncompressed, DV, JPEG '15:1' and JPEG '2:1'. For this production, we encoded the recordings to '15:1' and '2:1' (offline and online qualities, respectively) using open source tools from the Independent JPEG Group (4). The audio was encoded as linear PCM.

In conventional tape-based post-production, timecode and spool number are used to locate the content referred to in the PA's notes. To maintain a familiar way of working, we included metadata in the MXF files that identifies a source tape and start timecode. Although this is not a standard feature in MXF, it is supported by Avid through their support of AAF features. The appearance within the editor is that the file had been produced by ingesting from tape, even though there need be no recording on physical tape. This method provides good compatibility when a mix of tape-based and file-based ingest is used.

MXF is closely related to Advanced Authoring Format (AAF) and the software developed for creating these MXF files is based on the open source AAF toolkit, AAF Association (5) (6). The elements developed specifically for this application are available open source as part of the IngeX project (1).

Post production

To automate the ingest stage prior to editing, the logger application has the facility to export an Avid Log Exchange (ALE) file which lists all the good takes with timecodes, spool numbers, item details and comments. The timecodes include short "handles" before and after the marked beginning and end of each take to allow some leeway when editing.

When tape-based production is being used, as it was for our first trial, the ALE file can be imported into an Avid 'bin' and then all the required material can be ingested from tape via a 'batch capture'. The operator only has to load the appropriate tapes as prompted.

Name	Tracks	Start	Duration	Tape	Descript	Comments
S015-00_T4_Main	V1 A1-4	11:48:16:08	34:04	BRD251630	ZOOK LINE-UP, COUNTDOWN, 1ST CONTEST	RICHARD GOOD BUT CHILD TOO LONG
S015-00_T6_Main	V1 A1-4	11:50:07:08	1:10:16	BRD251630	ZOOK LINE-UP, COUNTDOWN, 1ST CONTEST	GOOD EXCEPT CHILD FLUFFED AT END AND TO
S015-01_T1_Main	V1 A1-4	11:53:13:00	13:03	BRD251630	ZOOK LINE-UP, COUNTDOWN, 1ST CONTEST	GOOD JAKE INTO COUNTDOWN
S015-02_T2_Main	V1 A1-4	11:52:43:16	18:07	BRD251630	ZOOK LINE-UP, COUNTDOWN, 1ST CONTEST	
S017-00_T1_Main	V1 A1-4	11:54:45:10	49:11	BRD251630	1ST CONTEST RE-RUN FOR CU'S	ALSO BETTER COMMENTARY FROM RICHARD
S020-00_T4_Main	V1 A1-4	09:56:01:16	29:03	BRD251630	INTRO TO 2ND CONTEST & SEND TEAMS BAC	
S021-00_T1_Main	V1 A1-4	10:46:11:02	1:18:00	BRD251630	GREEN TEAM CHOOSE ZOOK FOR 2ND CONT	CHOOSE BOXER GUY AT 10:47:17
S021-01_T1_Main	V1 A1-4	11:12:31:01	1:57:20	BRD251630	RED TEAM CHOOSE ZOOK FOR 2ND CONTEST	RUN IN NG - TECHNICAL

Figure 4 - Clip metadata in Avid Media Composer bin

This system worked well, although there were some cases when timecodes had to be adjusted manually. This happened when the VT recorders had been stopped too soon after (or even before) the timecode logged for the end of the take.

For the later tapeless production trial, we again used an ALE file, exported from the logger, to populate an Avid bin with a list of the required clips. However, the corresponding MXF files were copied into a suitable media directory on the Avid system and, after a 're-link' operation on the bin, were then immediately available for use. The matching of clips in the bin to files is done on the basis of tape name (spool number) and start/end timecodes.

Again, this process worked very smoothly. For the operator, there was little difference from tape-based working, other than the elimination of the time taken to ingest the content.

FURTHER DEVELOPMENTS

During the BAMZOOKi studio recordings, logging occurred as a live activity while recordings took place. An enhancement under development is a review and logging application so

members of the production team can fill in missing logs or improve existing logs outside the studio environment. The review application would reside on a portable, perhaps bus-powered, USB hard drive which would also contain proxy versions of all recorded clips. Updated logging data entered by the user is written back to the USB drive for use later in the edit suite. In addition to studio recordings, this facility can be used to log rushes from location shoots and any other material to be used in post-production, so that all material in the edit suite will be consistently and accurately logged.

The ALE file format was used in the BAMZOOKi production to transfer clip metadata into an Avid editor. Current developments use AAF (5) which can transfer the same data as ALE but, due to its ability to carry more complex metadata, has a number of advantages over ALE. For example, multi-camera groups can be directly imported into an Avid bin avoiding the manual and error prone manipulation otherwise required to create such groups. In addition, AAF can import a sequence directly into a project, allowing for example, vision mixing decisions captured from the studio to be represented as a sequence of cuts on the timeline.

Serial drama and other programmes which have continuous shooting and editing cycles offer another opportunity for workflow improvements. Development work has been completed on software to allow multiple Avid editing clients and other editing clients to access MXF files captured from the studio, immediately after each take is recorded. This software, named MediaHarmony, uses the Samba Virtual File System (VFS) to support the different requirements of some editing clients, as illustrated in Figure 5. For example, after applying the 'alldrives 1' console command, an Avid client can mount a Samba network share but expects to have exclusive access to the Avid-specific database (.pmr and .mdb) files in a media directory. When two or more clients use such a share and new MXF files appear in the media directory, conflicts over the database files can arise and cause deadlocks. The MediaHarmony VFS module keeps per-client copies of each .pmr and .mdb file but exposes only a given client's copy when the client accesses a file, avoiding all conflicts between clients. In addition, MediaHarmony can unwrap MXF files to support other editing clients which do not yet support MXF (such as Final Cut Pro) but which can support raw DVCPRO50 files for example.

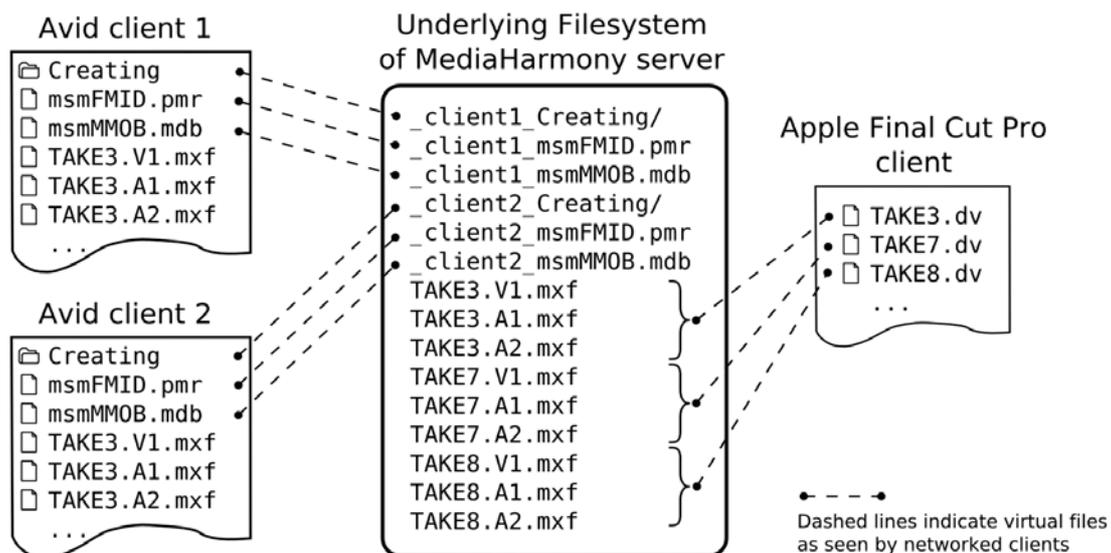


Figure 5 - MediaHarmony Virtual File System

Since the last series of BAMZOOKi, we have extended the media codecs supported by the Ingeg software. The JPEG 2:1 and 15:1 resolutions have been extended to 3:1, 10:1 and 20:1, while the DV family has been extended to DVCPRO50. MXF wrapped uncompressed

support has been extended to cover 10-bit and HD resolutions, while work to provide DVCPROHD is underway. The support for uncompressed HD and DVCPROHD (when completed) along with completed support for HD SDI capture cards, allows the entire tapeless and paperless system to migrate seamlessly to HD productions.

The use of MXF in equipment throughout the broadcast chain has allowed software components supporting MXF to be re-used to improve workflows in other production areas. BBC Sport is planning to capture some World Cup footage using Panasonic P2 cameras, allowing laptop-based editing software to be used in the field. Once an edited sequence is finished it needs to be played out, but the laptop does not have the specialised interfaces of typical editing equipment. As the P2 camera implements a constrained form of OP-Atom described in a SMPTE Recommended Practice, we have developed a tool to re-wrap the Avid MXF clip into a P2-compatible MXF clip. This enables users to make a file-based transfer to the P2 card, and subsequently play out their finished clip directly from the P2 camera.

CONCLUSIONS

This work has shown that in television production, electronic capture of the recording log and tapeless capture of the audio/video content both produce demonstrable efficiencies in the workflow. Each technique gives a benefit in its own right but used together, they open up many new possibilities: automation of the process from studio to post-production becomes possible and the ability to review and select content prior to editing is also greatly improved.

The use of MXF and AAF standards enables interoperation with different professional edit systems. Furthermore, we have successfully demonstrated how low-cost commodity network storage can be utilised to provide large scale media storage, serving shared content flexibly, as may be required for a variety of editing systems.

We have proved this overall approach by using it for the production of the third series of the BBC children's programme BAMZOOKi.

Our system was based on commodity IT components and open source software, with a hardware cost in the region of €20000, illustrating how the increasing performance of such equipment means that specialised hardware is no longer required, even for full broadcast-quality productions.

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