into the digital archive. A place is recorded on digital media by ubiquitous recording to capture its varied sonic environment, for example, traffic; buildings and architectures; spatial arrangement and perspectives; home and household; media practice; language and dialect; or physical objects that are part of the larger sound environment. The field recordist will approach a methodology to search for a wide sonic variety, frequent unexpected aural juxtapositions, documentation of disappearing and new sounds and spatial associations. The collected sound and other media can contribute to recording our very own environment onto digital media in order to create an archive of locative ambience.

The stand-alone personal archives can be organized by peer to peer networking of discreet digital repositories on hard disc drives lying in separate places; in this way file sharing can be achieved. To disseminate the separate archives into collective archival practice, events like workshops and discussion sessions, joint field recording expeditions, sound walks and listening-recording sessions can be arranged under an organizational banner. The archiving methodology includes collecting media content recorded in the field, digitizing existing materials on other formats like MD and tapes, standardising practice in keeping original recording as BWF and dissemination into online sharing, like blogging, in MP3 streaming at 192 kbps stereo files. For the latter, maintaining authorship by data encryption including id3 tags can organize the distribution of AV files for sharing and access online and networking.

Conclusion

As ubiquitous recording pertains, archiving in the digital domain becomes an activism. When recording becomes part of everyday life, archiving the everyday transcends mere institutional frameworks and moves into the public sphere. This involves raising consciousness of locative audiovisual heritage and promoting a culture of archiving practices at large, which in turn broadens awareness about audiovisual media archiving and its contribution towards ecological balance.

Easy access to environmental and natural everyday ambience formulates spaces and provides scope for their valid dissemination into newer media outputs. Dissemination of locative media archives into new media productions like documentaries, soundscape works and media installations for commercial/non-commercial curation/reuse, opens up doors of archival practice in the larger public domain and raises the potential for new kind of archives.

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I Took the One Less Travelled By: DAT Migration at Radio New Zealand's Sound Archives / Nga Taonga Korero

Tim Bathgate, Radio New Zealand Sound Archives / Nga Taonga Korero

1. Introduction

A significant portion of the archival material held by Radio New Zealand's Sound Archives/ Nga Taonga Korero (SANTK) has been recorded on Digital Audio Tape (DAT). These recordings are regularly accessed for research, re-broadcast, and general interest and are considered to be a priority for migration.

The New Zealand state broadcaster has generated the vast majority of these recordings in-house, and the homogeneity of the recordings (both in content and quality) is evident. It is thought that the controlled nature of the recording environment; the contiguous and predictable content; and the sheer volume of material (approximately 6000 hours) will lend these recordings to mass, unmonitored migration.

SANTK has identified several possible solutions for migrating DAT data en masse, each with varying degrees of quality reporting, reliability and cost. This paper is a product of an internal effort to research and evaluate one of those solutions.

2. Proposed Solution

Based on the unofficial reports from other sound archives, and recognition in the professional literature (IASA, 2009, p. 67), it has been suggested that the use of Digital Data Storage (DDS) tape drives in conjunction with appropriate firmware and software could be an efficient and cost-effective means of migrating data from our DATs.

The aim of this paper is to determine whether or not the architecture of such a system is reliable enough for use in a sound archive: is the decoding, error reporting, error correction, and error concealment as robust as other, traditional methods of migration?

3. Alternative Solutions

3.1 Monitored Transfer

Although not an option for SANTK, it is worth noting that monitored transfer has been used to facilitate the preservation of small collections in the past. This technique sees DATs transferred one by one, and both the audio and the error display on the DAT machine are monitored to determine whether or not interpolation or muting occurs during the transfer.

This is seen as a valid migration method by many archives (Casey & Gordon, 2007, p. 32), but the size of our collection negated the possibility of adopting monitored transfer as the primary strategy for migrating our collection.

3.2 Mass Migration Solutions

There are a number of products on the market for handling the mass migration of audio from DAT. These systems tend to comprise a bank of DAT machines connected to a PC via a digital audio connection. These machines are typically modified to enable the transmission of error status data from the machine's Error Detection and Correction (EDC) circuitry to the host PC for interpretation and logging.

3.2.1 Benefits

The most obvious benefit of adopting such a system is the ability to log metadata pertaining to error detection and correction directly from the EDC circuitry, as recommended by IASA (2009, p. 67). In addition, these systems are able to take advantage of the ability for digital connections to transmit sub-code data, which can be logged alongside EDC data in a metadata file, thereby producing a robust information package with little human intervention.

From an administrative perspective, these systems might be desirable due the availability of support from vendors; institutions will have to make their own support arrangements whenever an alternative in-house solution for migrating DATs is adopted.

3.2.2 Limitations

There are obvious limitations to these systems. Firstly, these solutions are often marketed at a price point that is exclusionary for some institutions. This is usually due to the premium that is placed on generic (but mandated) PC hardware and supporting software, but it might also result from a diminished buying power, which will be dictated by the economy in which these archives operate.

In addition, the output of the EDC module can only be transmitted by Sony PCM 7030, 7040, 7050 and R-500[69] (Cube-Tec, 2009; NOA Audio Solutions, 2009) DAT machines. As such, it forces institutions to purchase specific units, which might be sold at an inflationary price point due to the artificial scarcity that this situation dictates.

Finally, the DAT machines themselves impose two 'hard-wired' limitations. Firstly, the devices are limited to migrating audio data in real time. As such, an institution will need to purchase more than one machine and software license in order to achieve a substantial rate of throughput. Furthermore, the Sony PCM 70x0 series recorders do not, apparently, support replay of 32 kHz and 'long play' (32 kHz, 12-bit) DATs.

3.3 EDC Circuitry Interface

IASA TC-04 (International Association of Sound and Audiovisual Archives, 2009, p. 67) calls for '… measurement of the errors produced at the error correction chip of the replay machine and this information must be recorded in the metadata of the resultant audio file'. As such, any technologies that could enable such measurements were explored over the course of this research.

3.3.1 DAT Errormonitor

WPN Systems markets a solution for logging the error status data produced by the EDC circuitry, dubbed Errormonitor (WPN Systems, 2006). Unfortunately, Errormonitor is only capable of interfacing with DAT machines that employ the Sony CXD2601 error correction IC. The following machines have been identified as being compatible with Errormonitor:

- Sony DTC-55
- Sony DTC-57
- Sony DTC-77
- Sony DTC-670
- Pioneer D-500

SANTK was not able to benefit from this technology due to the unavailability of these specific devices.

3.3.2 Other Innovations

A more basic system, which reports uncorrectable errors using an LED, is described by Kaluza (1996). Once again, Kaluza's schematic is only compatible with DAT machines that employ the CXD2601 IC.

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[69] Error output from the R-500 is enabled by circuitry designed by WPN Systems and licensed to NOA Audio, etc.

3.3.3 Observations

It seems possible that, by reverse engineering other common ICs that are responsible for error detection and correction, a series of circuits could be designed for common archival DAT playback devices. Without further research, it seems unlikely that many sound archives will gain the ability to capture error status metadata.

4. Digital Data Storage

4.1 Overview

The Digital Data Storage (DDS) system was first mooted in 1989, six years after the DAT Conference was established and four years after the DAT technical specifications were first published (Goto, Asada, Chiba, Sampel, Noguchi, & Arakawa, 1989, p. 1). It was developed as a format for storing and backing up data onto magnetic tape. As of 2009, DDS is still a contemporary means of storing data, though the form factor of the tape was altered in 2007 with the advent of DAT 160, which uses 8mm wide tape instead of 3.81mm. 3.81mm tape was used for DDS-1 through to DDS-4, and DAT 72.

The DAT specification was chosen as a foundation for DDS due to the 'large capacity, high speed search function, and direct addressing by sub-data search' (ibid.) that are intrinsic in the DAT specification. To take advantage of these characteristics, the engineers of the system envisioned that the system would mimic a standard DAT device, but with a 'data processing unit' (Figure 1) handling a signal, rather than an ADDA converter (ibid. p. 661). The DDS system would employ the same error correction as a standard DAT machine, but with an added error correction code – dubbed C3. This error code differs from C1 and C2 error correction, in that it is interleaved over many tracks (Figure 2).

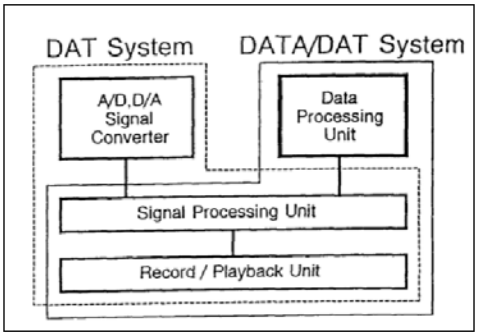

Figure 1: Comparison of DAT and DDS Input/Output (IO)

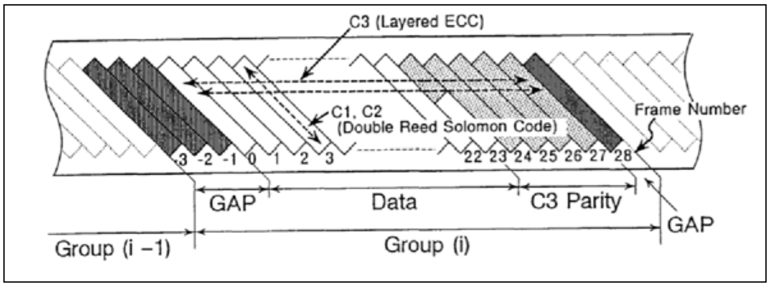

Figure 2: Arrangement of C1, C2 and C3 error correction codes

4.2 Comparison with Digital Audio Tape

The similarities between the mechanisms of a standard DAT machine and DDS drive are evidenced in Figures 3 and 4. These similarities are such that a DDS drive, when loaded with appropriate firmware, is able to interpret the unique arrangement of audio and subcode data and transmit that data across its SCSI interface. In addition, the firmware allows for some measure of control over the transport (i.e. fast forward, rewind, play, stop, record).

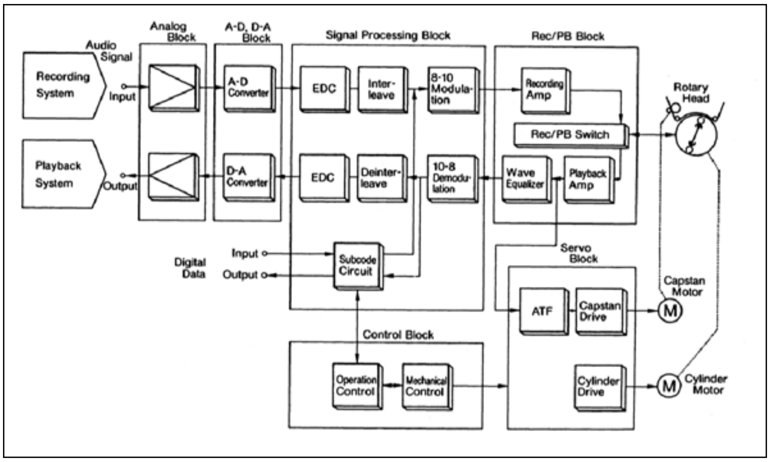

Figure 3: DAT Block Diagram

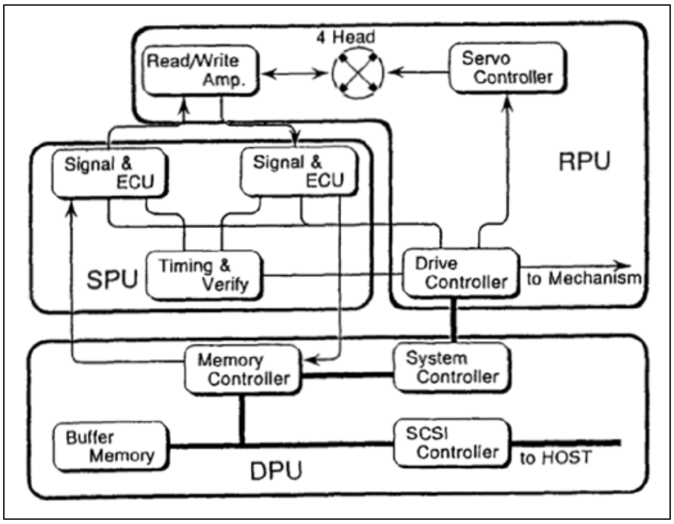

Figure 4: DDS Block Diagram

Aside from the substitution of a Data Processing Unit (DPU) for the Analogue to Digital/Digital to Analogue (ADDA) converter, there are two crucial differences in the implementation of the Error Correction Unit (ECU) and the rotary record/playback head in a DDS system.

In a standard DAT machine, the EDC circuitry is responsible for identifying and correcting correctable (C1 and C2) errors and concealing uncorrectable errors. Errors are considered to be inherent in the media, and are catered for by the error detection and correction subsystem (Pohlmann, 2005, p. 216). Error concealment is employed whenever the capability to correct objectively is exceeded, and these errors are concealed using methods such as interpolation or muting (Pohlmann, 2005, p. 176).

Although an EDC circuit is present in the DDS system, this module is only responsible for correcting C1 and C2 errors. Corrupt data will be transmitted as is (usually with the value of the last known uncorrupt sample held), but flagged as uncorrectable.

This inconvenience is, perhaps, mitigated by a second distinction: the rotational speed of the record/playback head in a DDS system. The head in a standard DAT machine rotates at 2000 rpm, whereas the rotational speed of the head in a DDS system is 4400 rpm for DDS-2 and 8800 rpm for DDS-3.

Because the extraction of audio data is an 'offline' process (i.e. the system is not expected to produce an output that will be interpreted in real time, as with a standard audio DAT machine), the faster rotational speed allows data to be ripped at as much as 2.2 or 4.4 times speed.

There has been some concern over the stresses that the faster speed might have on degrading carriers (private communication with Jörg Hourpert, 2009), though there has yet to be any published investigation into this issue.

5. 'Literature' Review

5.2 DATHeads Digest

The DATHeads Digest appears to be the domain that first spawned discussion over whether a DDS-based solution was viable in a 'prosumer' setting. As early as 2001, the 'early majority' begins to enquire after other users' experiences with extracting audio data with DDS drives; the 'late majority' does not catch on until 2005.

The early adopters express enthusiasm over the new technology's potential to save time when duplicating recordings (Zuccaro, 2001) and make copies of DATs that are protected by the Serial Copy Management System (SCMS) (Shudtz, 2001). However, there is an extreme dissatisfaction with the stability of the extraction software (Shudtz, 2001).

Later postings are more positive, and this method of migration appears to be acceptable practice amongst DAT hobbyists and studio engineers.

5.2 ARSCList

A Google search targeting the archives of the Association for Recorded Sound Collections listserv for the term "DDS" returns several inquiries into the establishment of a DDS-based migration solution, and a handful of user experiences. The discussion in this forum appears to be concerned more with using a DDS-based solution in heritage institutions.

What comes across in these postings is that the difficulties in constructing such a system are rooted in the specificity of the hardware/firmware combination for the drives themselves (Irelan, 2009). In addition, we learn that the system has proven to be unreliable under certain conditions:

> I don't have absolute faith in it, since I have found instances where the program fails to correct some errors, and some instances where it will skip a portion of the audio without flagging it, but this seems to happen when I am doing other things on my computer while extracting a tape… (Sohn, 2009)

However, the number of positive reports appears to outweigh the negative. A number of posters (Rice, 2007) laud the ability to extract data faster than real time, log corrupted frames, split the resulting files according to their track markers, and extract recording creation dates (in some instances). This positive feeling is echoed by Prentice (2009), who sees an archival application for such a system:

> Despite the problem with this approach, one big advantage… is the ability to accurately identify the presence and location of uncorrectable errors. Whether these errors are audible, or how you choose to address them having discovered them is another thing, but wherever it is possible to measure the success of a digital data rip in an archival environment, my feeling is it should be pursued.

5.3 Other

Aside from these listservs, the vast majority of information on this topic appears to be stored in the backwaters of the internet. Perhaps the most valuable resource for information on configuration is maintained by Computall Services – the developers of DAT2WAV. The site links to a number of resources, many of which are only accessible using the WayBack Machine at archive.org.

What this highlights is the ephemeral nature of information on fringe technologies such as this. Should archives adopt this method of migration, it seems important that this information is collated and verified.

6. Implementation

6.1 Procurement

Based on recommendations from other archives, Ultra Tec – 'A UK-based distributor specialising in stocking end-of-life and discontinued storage products' – was chosen as a supplier for DDS tape drives as they were able to provide the drives with the appropriate firmware already installed.[70] As of August 2008, these drives were priced at £125 each.

We purchased eight drives – the rationale being that the SCSI bus can support seven devices, so we could keep one in reserve – and we were sent eight Seagate CTD8000R-S drives, each annotated with the Compaq OEM part number 199464-201. The EEPROM had been flashed with the ARCHIVE Python 01931-XXX5AC firmware.

The CTD8000R-S is a DDS-2 device that was produced using technology from Archive under ownership of Seagate. In hindsight, it might have been better to search for Sony SDT-9000 DDS-3 drives, which are capable of extracting at a higher speed due to the faster rotational speed of the head.

6.2 Installation

The system was built by Radio New Zealand's IT department over a period of approximately nine months. The installation period could have been much shorter, but there were a number of issues and inefficiencies in the way the project was handled.

The reliance on legacy SCSI components complicated matters. Given that a modern IT department is unlikely to encounter SCSI when interfacing devices with office PCs, it is only natural that the process of building a legacy system will require some degree of research. For this reason, the identification, procurement and installation of PC components caused major delays. These issues might have been simplified by using a SCSI to USB converter, or, perhaps, more invested personnel.

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[70] There has been some criticism regarding sourcing DDS drives from suppliers such as these. Unpublished research by one company suggests that the supplied drives are typically refurbished units, and are prone to failure or inconsistency across drives (private communication with Jörg Houpert, 2009). These issues were not adequately covered by the research, and it should be recognised that one of our drives did fail after only 15 hours of operation; consistency across drives demands further investigation.

In addition, a series of software glitches slowed progress. These issues were largely due to conflicts between the software and the installed Adaptec ASPI driver.[71] On the advice of the VDAT developer, we installed the Adaptec ASPI driver 4.60 build 1021, which cured the issues.

7. Experimentation

7.1 Tools

7.1.1 Wavelab

In the following experiments, Wavelab 6.10 was used as the primary analysis tool; in particular, the Audio File Comparer and the Bit Meter.

The Audio File Comparer was used to count the number of discrepancies between two otherwise-identical Wave files. It was also used to generate a 'delta file' – a file that is produced by reversing the phase of one Wave file and subtracting it from the other to produce a file exhibiting only the discrepancies .

The Bit Meter was used to sample-align Wave files and compare the binary values of specific sample positions.

7.1.2 Bit By Bit

Bit By Bit is a utility that was built specifically for this project. It was commissioned after we determined that the comparison functions of Wavelab could not offer enough data to quantify the differences between two Wave files.

Bit By Bit takes two Wave files and compares the values for each PCM sample. It then generates a log file that reports any discrepancies. The log file lists the sample number and time at which a discrepancy occurred, and displays the binary and decimal values of the conflicting samples.

This tool was instrumental in determining *just how different* two near-identical bitstreams were, and measuring the consistency of error correction operations.

Wavelab has a similar function, which allows a user to output sample values as ASCII, though it lacks functionality for carrying out comparisons.

7.1.3 Extraction Software

VDAT

VDAT is a Windows application that is designed to extract audio data from an array (i.e. as many as are available) of audio-capable DDS drives (private communication with Eduard Ungemach, 2008). The software is written by a German developer, Eduard Ungemach, and the latest version (0.6h) was released during 2007. As of 2009, VDAT is still being sold for 100 Euros directly from the developer, though his website is apparently defunct.

VDAT is set apart from other software packages for its ability to manage many streams of data. This feature is of paramount importance in most archival environments , due to the volume of data the needs to be migrated.

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[71] Despite recognising the tape drives, the latest version of the driver would cause Visual Basic C++ runtime error; 'command aborted' error; an Application Error stating "The instruction at "0x10001130" referenced memory at "0x10001130". The memory could not be 'read'"; and errors that didn't say anything.

In addition, VDAT is controlled via a Graphical User Interface (GUI), which makes operating and monitoring a transfer very simple. The interface comprises transport controls; displays for Absolute Time (ATime), Program Time (PTime) and Running Time (RTime); sample rate; and SCMS status.

The extraction can be executed in three ways. VDAT can respond to subcode data, and split the resulting files according to track number; VDAT can ignore track IDs and generate a single Wave file; or VDAT can ignore subcode altogether and extract data from every frame on the tape (even when that data is outside the bounds of the first Start ID and the End ID).

VDAT creates a log file that will record events that might compromise the quality of the resulting bitstream. The most important of these is the BadFrame event, which indicates that a frame could not be recreated using C1 or C2 error correction.

DAT2WAV

DAT2WAV is a DOS application that is manipulated using the command line. The latest version of the software (1.3b) was produced in 2007 by Computall Services and is currently marketed as freeware.

DAT2WAV performs similarly to VDAT, though it tends to fail when more than two extractions are carried out at once. The most noteworthy feature of DAT2WAV is its error concealment feature. A user is able to choose whether error concealment is applied to corrupted frames, and this action is written into a log file.

A small sample experiment suggested that the error concealment algorithm of a Tascam DA-40 was more likely to mute corrupted frames, whereas the DAT2WAV algorithm interpolates by substituting a sample value that is the average of the uncorrupted samples on either side. Interpolation by this method tended to sound less obtrusive than muting. Whenever interpolation was used by both the DAT machine and DAT2WAV, the average discrepancy was +/- 11 869 levels of quantization (approximately 5.5% of the resolution of a 16 bit sample).

What this suggests is that, in some instances , a software tool may be more appropriate for mending corrupt data than the error correction circuitry of a DAT machine. Experience suggests that the error concealment logic of an EDC circuit is not ideal and that DAT error concealment might be a task that is better suited to human intervention.

DATXtract

DATXtract is a Mac OS X based application, produced by Peter DiCamillo and marketed as freeware. DiCamillo has also posted the source code for his application online, and encourages modification by third parties (private communication with Peter DiCamillo). The most recent version (1.3) was released in November 2007.

Like VDAT, DATXtract is controlled via a GUI. In addition to standard transport controls and position data (i.e. ATime, etc.), DATXtract reports errors in real time, allowing an operator to monitor any abnormalities during the transfer process.

Unfortunately, DATXtract is only capable of extracting data from one device at a time. However, communication with the developer suggests that it would be possible to implement support for parallel extraction (private communication with Peter DiCamillo).

Comparison Chart

Software	Platform	Cost	GUI	Output Format	Support for Multiple Ingest	C1 and C2 Error Reporting	Uncorrectable Error Reporting	Error Concealment	One WAV Per DAT / One WAV Per Track
VDAT	Windows	100 €	Yes	WAV	Yes	No	Simple	No	Yes
DAT2WAV	DOS	Free	No	WAV	Some	No	Cryptic	Yes	Yes
DATXtract	OSX 10.2-10.5	Free	Yes	AIFF	No	No	Simple	No	Yes

7.2 Experiment One: Ideal Conditions

7.2.1 Aim

To determine whether a standard DAT machine produces a different result to the DDS-based extraction method when reading a DAT produced under controlled, ideal conditions.

7.2.2 Method

A commercially released Compact Disc was selected and played using a Tascam CD-RW2000. The resulting signal was transmitted to a Tascam DA-P1 DAT machine via S/PDIF, with synchronisation supplied by the Tascam CD-RW2000, and recorded. This was expected to generate a bit-identical copy.

The CD was then ripped using Exact Audio Copy, which would verify the integrity of the rip by comparing the checksum of the resulting Wave files to an online database containing a series of checksum values for the same CD.

The DAT was played back using a Tascam DA-40 (a different playback machine was used to negate any bias that might have occurred from using the same recording device for playback) and the output was transmitted over an AES/EBU connection to a Lynx L22 soundcard and captured as a Wave file by Wavelab. The Tascam DA-40 was used as a synchronisation source.

Immediately afterwards, the same DAT was migrated using a DDS drive and the VDAT software.

The two files were aligned and compared.

7.2.3 Results

Wavelab's Audio File Comparer indicated that the two files were identical.

7.2.4 Conclusion

The results of this experiment suggest that, under ideal conditions, there is absolutely no difference between the output of a standard DAT machine and a DDS drive. This verifies the integrity of the system's architecture, and justifies further investigation.

7.3 Experiment Two: Ideal Archival Conditions

7.3.1 Aim

Having proven that the DDS method is viable for recordings generated under ideal conditions, it was important to determine whether the method might be suitable for migrating DATs that have been created and stored in a manner that could be considered 'ideal' from the perspective of an archive.

The aim of this experiment was to compare the bitstream produced by a DAT machine and a DDS drive when decoding a DAT tape created and stored under ideal conditions.

7.3.2 Method

A sample of DATs produced by Radio New Zealand and stored by SANTK was identified and transferred using the method outlined in 6.2.2. The bitstreams were then compared with Wavelab and Bit By Bit.

7.3.3 Results

The VDAT log files for each bitstream reported 'bad frames'.[72] Upon listening to the Wave files, it was discovered that the corrupted data was not audible; this is probably due to the very short period and relative isolation of each corrupt frame.

When compared with the audio DAT machine derived bitstream, it was shown that inconsistencies were minute: the number of non-identical samples did not exceed 0.0087%.

Of particular note, a file resulting from one of the DATs that was transferred with a standard DAT machine presented with significant digital artefacts at several points. Bit By Bit revealed that this was due to the application of muting by the DAT player; the DDS-based drive was able to interpret these samples successfully.

7.3.4 Conclusion

A DDS drive interprets and transmits data as well, if not better, than a standard DAT machine when decoding DATs that have been stored under archival conditions for a period in excess of 17 years. These findings suggest that uniform collections could be reliably transferred using a DDS drive as long as the error logs are checked and the bad frames auditioned.

7.4 Experiment Three: Non-Ideal Conditions

7.4.1 Aim

The viability of the DDS migration method has been demonstrated for recordings that have been made and stored for posterity. This experiment will determine whether or not the DDS method is suitable for recordings whose error rates exceed the capabilities of C1 and C2 error correction.

7.4.2 Method

The DATs produced for Experiment One were fast-forwarded to 00:25:00:00 and ejected. The cartridge was then opened to reveal the tape. Approximately one metre of tape was pulled out and strewn across a clean surface (so as not to introduce dust into the cartridge which could damage or dirty the tape heads of a playback device). This section of tape was then subjected to a tape degausser for several minutes, then scrunched into a ball and wound back into the cartridge.

The tape was then played back between 00:20:00:00f and 00:30:00:00f using a Tascam DA-40 while the error count was displayed on the front panel. The error readings and their Absolute Time position were recorded by hand in a log.

The entire tape was then migrated using a DDS drive in conjunction with the VDAT software.

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[72] A 'frame' is a pair of adjacent tracks with azimuths of opposite polarity that comprise approximately 1440 samples (30 milliseconds) at 48 kHz. A 'Bad Frame' is reported by VDAT whenever C1 or C2 error correction cannot be applied successfully.

The positions where high error counts were logged were checked in each file, and a delta file was generated to examine the positions at which error correction was not applied in concert by the two devices.

7.4.3 Results

Analysis of the two files revealed that 2.05% of the samples from each bitstream differed in value. This is a significant discrepancy when compared with the results in Experiment Two. This suggests that the error concealment of the two systems, predictably, is dramatically different.

Surprisingly, aural analysis of the two files suggested that the DDS system produced a more coherent bitstream than that of the standard DAT machine. In many instances, it appears that the DDS drive was able interpret the 'corrupted' samples whereas the DAT machine chose to mute or interpolate. This is consistent with a posting on the DATHeads Digest (Campbell, 2005), which suggests that the DDS drives might be able to read data when a standard DAT machine cannot.

This test was repeated using different DAT machines and similar behaviour was observed.

7.4.4 Conclusion

The results of this experiment have challenged commonly held preconceptions of the viability of DDS-based DAT migration. It would appear that allowing a DAT machine to employ its own error concealment algorithm is not ideal, and, assuming that a DAT player is a 'trigger-happy' system, error concealment might be more appropriately applied by humans as part of an offline process.

8. Pilot Project

8.1 Overview

The testing described in Section 7 suggests that the underlying architecture of a DDS-based migration system is not inappropriate for use in an archival setting. As such, it was decided that a pilot project should be carried out to determine whether it was possible to adopt such a system for a large-scale migration programme.

A collection of 100 DATs was chosen for the pilot project and an operator was charged with migrating those DATs using any of the tools outlined in Section 7 .1. The operator's primary directive was to migrate the collection to BWF, and append any metadata that might attest to the integrity of the bitstream in the future. In addition, errors would be checked and concealed (if appropriate) and the operator would document their actions.

The operator would keep a diary to document their experiences and log their throughput.

8.2 Results

It was found that, using only two drives, which extracted PCM data in parallel, an operator was able to migrate roughly four hours of audio per working hour. This included spot-checking of data, concealment of any data that was flagged as corrupt and did not manifest as an inaudible corruption of the least significant bits, manual grooming of error logs, and attachment of metadata to the BWF header.

By extrapolating these results (inferentially, not mathematically), it was determined that a lone operator, working with a stable system comprised of seven DDS drives and a single terminal, might transfer between 10 and 12 hours of audio per working hour.

9. Conclusion

Inductive logic suggests, based on these observations, that Digital Data Storage technology is not categorically inappropriate for use in an archival setting: that is to say, an archive that employs DDS drives to migrate its collections could assume that the DDS drive would produce an output that differs from that of a standard DAT player by no more than 2.05%, even under the most extreme conditions. Whether this is an appropriate discrepancy or not will be dictated by the archive, probably under advisement from other practitioners and the professional literature.

In reality, the disparity is likely to be much lower, and a DDS-based migration may even result in better transfers if the software is able to identify and report uncorrectable errors with absolute accuracy (i.e. where error concealment is applied by a human, rather than an EDC circuit).

This is an important conclusion, both for audiovisual archives with significant DAT collections and for our sector as a whole, and its implications will be discussed in the following section.

10. Discussion

10.1 Institutional Relevance

As has been discussed, there are several options available to archives that intend to migrate their Digital Audio Tapes. However, it is likely that there will be several issues affecting a given institution that will determine which solution is most practicable.

For small institutions with limited resources, or large institutions with relatively small DAT collections, it is inevitable that a commercial solution is unlikely to be viable, due mostly to cost. In these instances, we can assume that there are several possibilities for migration: unmonitored transfer, monitored transfer, outsourcing, or DDS-based migration.

It is obvious that the DDS-based solution would be particularly relevant to this institutional configuration, mostly because the benefit-cost ratio of the hardware is very favourable, and the system is capable of migrating DATs with an efficiency and efficacy that might not be available with monitored or unmonitored transfer. Moreover, the solution allows DATs to be migrated on-site, which saves an archive from putting their recordings through the stresses of transit that might occur if outsourcing were chosen.

For medium-sized institutions with collections that demand mass-migration of DATs, the only realistic options are a commercial solution, outsourcing, or DDS-based migration. In this instance, the viability of a commercial solution or outsourcing is likely to be much higher, though there are still non-financial pressures that might prevent the adoption of these strategies.

Firstly, it might be difficult to justify investment in a mass-migration solution for DATs, given that the format was only popular in certain circles, and only for a very short period; if an investment were to be made in this technology, an archive might consider that its resources would be put to better use in acquiring technology that could be used to digitise a more prevalent format, such as open reel tape. This is certainly true at SANTK, though it seems likely that a satisfactory compromise could be reached whereby DDS-based migration would be adopted for stable DATs, and those that present with high error counts would be farmed out to a small-scale commercial system.

With regard to outsourcing, there are issues aside from that of transit that are concerning. or a medium-sized institution, which seems more likely than most to be reliant on specialised personnel,[73] the impact on staff of outsourcing work (and taking it away from those who probably know the collection best) must be given due consideration. In instances where outsourcing is impossible for this reason, DDS-based migration might be a suitable compromise.

In large institutions, whose collections span many tens or hundreds of thousands of DATs, I cannot see that a DDS-based migration solution is possible. The 'preservation factory' approach that these institutions are forced to adopt rely on simple, stable systems that are backed by automated data management processes, and the DDS-based system cannot offer these features.

However, there is at least one exception to this assertion: the BBC archive is known to have employed DDS technology (using four DDS drives per terminal in conjunction with VDAT software) to migrate some of their vast DAT collection with considerable success (personal communication with Simon Rooks, 2009).

10.2 Ongoing Research

10.1.1 Extraction Software

The major failing of this solution is the software that controls the migration process. This is often a source of massive skepticism amongst archivists, and is often cited as a fatal flaw (personal communication with Memnon, 2009). It is clear that better extraction software should be developed if this solution is to instill confidence in archivists.

At SANTK, we have explored the possibility of modifying DATXtract to meet our needs. My discussions with the developer of the software, and several software engineers, have suggested that the software is relatively simplistic and the improvements that we might expect would be trivial to implement.

Whether this project gains any traction or not remains to be seen. In the meantime, however, it is crucial that we attempt to preserve the software and related resources that already exist. It is already difficult enough to gather the disparate software components that the system requires, and the dissolution of any of the hosts of these resources would probably nullify the prospect of adopting or improving the technology.

10.1.2 Integration

To date, the software that controls the migration process has been built without regard for standards, or any of the demands of an archival community. As part of any development to the extraction software, integration with other tools and standards should receive significant attention. In carrying out these improvements, it would be best to look at the features of alternative systems for inspiration. For instance, specifying metadata prior to extraction and storing it in conjunction with quality data in a useful format is an absolute necessity.

In addition to these basic features, it is clear that a tool for carrying out interpolation is also crucial to improving the viability of this system.

10.1.3 Availability

Of course, there is little use in carrying out any development if the hardware is not available in sufficient quantities. Before any other research is carried out in this field, the question of availability has to be addressed.

In carrying out this research, it would be particularly useful for the researcher to ascertain how the availability of DDS drives that are capable of being impregnated with an audio-

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[73] Rather than one or two dedicated staff members, in the case of a small institution, or a division of labour approach in a large archive

capable firmware compares to the availability of DAT drives whose EDC circuitry can be probed to derive an activity output.

If neither suitable DDS nor DAT drives are available in sufficient quantities to satisfy the demand of our community, then we have a host of issues to address. These range from the practical issues, which are outlined below, to the philosophical questions, mostly ethical, that might arise upon learning of this reality (institutions and companies hoard DAT players to support their own institutions and products, for example).

10.1.4 Reverse Engineering

Should an extreme lack of availability be discovered, one cure might be to reverse engineer the most-available device to facilitate error logging. It is thought that this would be very difficult, but not impossible, for a DDS drive (personal communication with David Olson, 2009), and we can see evidence for successful reverse engineering of standard DAT players in the solutions that are outlined in section 3.3.

It is difficult to foresee how such a project might be funded, who might be responsible for carrying out the work, and how the benefit of this work should be shared. My expectation, in sharing this research, is that we will resolve to research these issues as a community in order to produce a solution that serves everybody. If we maintain the status quo – commercial solutions and outsourcing for some; monitored or unmonitored transfer for everyone else – it is inevitable that the collections of our neighbours will continue to languish in their vaults.

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