Creating an Indisputable Record

Advances in video encoding technology have generated a greater degree of post event situational awareness

In ATM, the role of the recording system has always been to provide an unequivocal record of communications used as an aid to air traffic services. Historically, audio has been the primary evidential material and even with the advent of controller-pilot datalink communication (CPDLC), where the spoken word is replaced by 'text messages' due to the saturation of voice communication channels, this trend will undoubtedly continue. In the voice communication market, even manufacturers with voice communication switch (VCS) solutions and voice recording capability recognize that the 'legal' recorder should be an independent platform to ensure that there is no ambiguity and that challenges to the quality or accuracy of the recorded data are frivolous.

Recording Development

ATC/ATM recording is carried out principally for four reasons: to support the post-incident investigative process; to support search-and-rescue operations; for training and simulation environments; and for the verification and validation of connected systems. In general, most ANSPs will deploy ATM recording systems in the operational environment, principally for the purposes of post-incident investigation, so the need for the content to be legally admissible in a court of law is of the utmost importance.

As a basis to provide an indisputable record, recording systems are passive, independent components, which tap into communications and safely store the data, irrespective of its format, quality or source. Such independence ensures that the data recorded is a replica of the particular environment in which events occurred, including performance and technology issues of connected systems as well as the controller communications themselves.

In ATM, X protocol-based recording has been the primary method of capturing a controller's screen in support of the objectives above, but is an extremely intrusive solution as software must be installed along with a software license on each controller workstation to be recorded. This software is recognized as using system resources (processor, memory, storage) and can sometimes introduce an additional central processing unit (CPU) load that may occasionally impact actual ATC application performance. X protocol recording solutions became standard because they were the only solutions that could capture what the controller saw until, in recent years, at-the-glass (ATG) video signal capture emerged as a viable alternative technology.

AirServices Australia training facility where EIZO Re/Vue products are installed

Synchronous ATG recording has developed as a real requirement as it is seen as a 100% accurate reflection of what a controller saw and did at a particular point in time by interfacing directly with the video signal. When synchronized with the recorded audio and other available data, it provides an unequivocally accurate version of events. Initially, ATG video recording technology was not mature enough to capture the 2K × 2K resolution used in ATM, even at very low refresh rates. Over time, manufacturers such as EIZO developed pixel -based solutions that offered lossless screen recording technology from 2K × 2K screens at up to 60 frames per second (fps). The recordings created by this new technology offered greater reliability along with much more portability and flexibility in file and data handling, and did not suffer from the drawbacks of X protocol-based recording.

Hardware-based solutions, such as EIZO's Re/Vue Series, are completely independent from the source itself and in some instances also contain local storage. Such solutions do not require software to be installed on the host workstation but do offer system integrators the ability to control, via an application programming interface (API), calls from within their own development environment.

Perhaps the most important feature of ATG recording is the pixel-perfect playback of the solution, which records exactly what the controller originally saw, frame-by-frame. By contrast, X protocol-based playback is a simulation of the original events. As a result, the timing of when objects appear on the screen is imprecise. This makes the effective frame rate variable and can cause incorrect time relationships. That is, given two objects in time and space, when they appear relative to each other may be changed by X protocol-based playback. This is not the case for an independent hardware solution.

Encoding and Compression

Early ATG recording solutions used industry standard compression algorithms designed for motion video and the broadcast environment. When handling typical ATM data, these algorithms do not generally provide an acceptable balance between image quality and file size. While image quality could be increased to an acceptable standard, the downside is the large amount of storage required for the data and the bandwidth to transport it. While storage and bandwidth become less of an issue as time progresses, image quality maintains its position as the single most important aspect. If the image is difficult to read or any ambiguity exists, then the recording is almost rendered useless as evidential material.

Lossless compression refers to a process that allows the original data to be perfectly reconstructed pixel for pixel from the compressed data. A compression algorithm can only be described as truly 100% lossless when it refers to the entire range of data. If lossless is used to refer to the encoding of each frame, but is encoded at a frame rate lower than the refresh rate of the monitor, the recording cannot be described as lossless as inter-frames are not sampled or encoded at all. Lossy – or irreversible – compression refers to a process that uses inexact approximations and partial data discarding to represent the original data. Such techniques are used principally to reduce data size for storage, handling and transmitting content, and only support an approximation of the original data. Lossy methods are especially suitable for natural images such as motion video in applications where minor (sometimes imperceptible) loss of fidelity is acceptable to achieve a substantial reduction in file size. Lossy compression suffers from data loss during the encoding, compression and decompression procedure by what is known as generation loss. This means that repeated compression and decompression of the data will cause it to progressively lose quality with every iteration – a process that is irreversible.

Visually lossless is a lossy compression that produces differences that are imperceptible to the human eye. The standard or threshold, if any, used to decide that the human eye cannot perceive the loss is very subjective. Typically such compression techniques are optimized for motion pictures and not data screens like those used by primary ATM monitors.

For a recording to be truly lossless, the data must be mathematically equivalent to the post-recording data that is played back. To achieve this, every video frame must be recorded. Given that the typical ATM primary display updates 60 times per second, a truly lossless

algorithm must be able to record at 60 fps. Only then do you have the guarantee that your recording will be truly accurate.

With so much focus being placed on the quality of the recording, it raises the question of how much storage is required for a lossless recording. 2K × 2K resolution means that each frame is four megapixels so with a bit depth of 24 bits, each uncompressed video frame is approximately 12 MB. This equates to 720 MB of data per second, or one terabyte of data every 25 minutes at 60 fps. Now consider that you may need to store 30 days' worth of recordings for multiple displays, and the storage requirements become astronomical. This issue was seen as the single biggest challenge to the adoption of ATG recording technology during its emergence.

To address the combined issues of file size, data integrity and performance, EIZO set about developing its own algorithm. The target was to provide a guarantee that any subsequent recording exactly matched what was displayed on screen at any point in time. EIZO's proprietary algorithm is used in its Re/Vue Mini line of recording and streaming products. These products are capable of achieving compression ratios of up to 30,000:1 even at 60 Hz, making it possible to record losslessly from a 2K ATM video source without needing vast amounts of additional storage.

The clear benefits of high compression are the reduced bit rate, network bandwidth and resultant storage. Figure 1 shows the results of encoding video at various source resolutions using industry standard lossy compression versus EIZO Re/Vue lossless compression. Not only does Re/Vue achieve greater compression, but it can do so at the refresh rate of the display, thereby achieving true lossless recording. As a result, there is no longer a compromise to be made for the recording of ATM data from primary control monitors.

Re/Vue Mini devices feature industry-leading compression for lossless recording while reducing file size

Due to the nature of typical ATM video, there is little advantage to reducing the frame rate from the native frequency of the monitor. The relationship between frame rate and compression is non-linear, so the reduction in file size is relatively small in relation to a reduction in capture frame rate. The guarantee of pixel for pixel, frame by frame encoding and recording is significant when measured against a solution that needs to reduce frame rate to maintain acceptable performance.

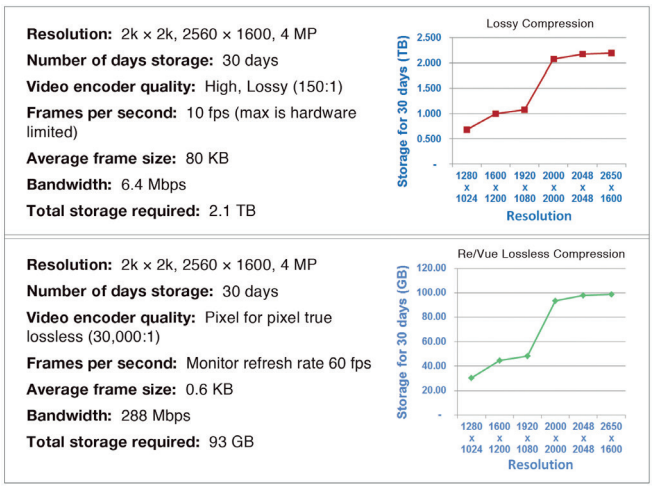

Figure 1: Standard lossy compression compared to EIZO

Re/Vue also supports the distribution of video data in a number of ways to ensure that the ANSP or system integrator has options for file handling. The Re/Vue Player application is a standalone player with no requirement for installation on the target system. It supports live streaming from attached Re/Vue devices in addition to the ability to playback lossless recordings at their native resolution and frame rate. System integrators have the option of embedding this application in their own environment or using a fully documented API to support recording in a third-party system.

True independence

If ATG recording capability is established as a viable option, one must then consider how to deploy such a solution. There are principally two options for the encoding of ATM video to consider – an independent encoding and streaming device or a combination of monitor and streaming in a single component. As an integral component of the monitor such a solution could in fact tap even closer to the displays from internal low voltage differential signaling (LVDS) video signals. Such integration would provide video encoding that includes elements such as on screen display (OSD) adjustments, if available, made by the user.

Furthermore, physical benefits include there being no requirement for an additional external power supply unit (PSU) (although further power is still required), less cabling and fewer interfaces, and no need to consider the 'split' of the video signal. All this leads to a neater local hardware solution and a streamlined console. However, despite these benefits, such a solution also has its drawbacks. Principally, we should consider that, as the encoder is an integral part of the monitor, it cannot be classed as a passive component and therefore could

EIZO's Re/Vue line of recording and streaming solutions

be claimed to affect the authenticity of the data. An external, independent, passive video encoding device ensures that the data is isolated from its source, thereby ensuring 100% data integrity.

In addition, consideration must be made for the decrease in the mean time between failure (MTBF) of the display, which hinders the monitor's ability to achieve its primary objective – visualizing the ATM system. Replacement of failed monitors is likely to be at a greater expense, due to their extended capability. With current technology, primary control monitors continue to operate within specification for five years or more, and a reduction in MTBF is potentially a backward step. Furthermore, once deployed it would be costly to deviate from this architecture in the future. Monitors from alternative manufacturers could not be considered at the time of replacement without also considering the cost of upgrade or replacement of connected recording systems. Without such further investment, the ANSP could be forced into a sole-source acquisition, which is rarely a beneficial position.

EIZO Solutions

EIZO's Re/Vue line of recording and streaming solutions offers devices that can be deployed as standalone systems or integrated into third-party recording equipment. They use EIZO's proprietary compression algorithm, which gives the highest ratio in the industry, supporting lossless recording at the monitor's frequency.

Re/Vue Pro is an encoding device that also uses EIZO's proprietary compression algorithm. This device is targeted at system integrators who wish to take advantage of EIZO's compression technology in a smaller, lower power, and higher availability device than Re/Vue recording products. Similarly, Re/Vue Lite is an encoding and streaming device that supports the connection of, typically, auxiliary monitors that will be used to display motion video. The device also has dual H.264 encoders for maximum availability. All Re/Vue products operate as external encoding devices, supporting the need for complete independence and thereby guaranteeing data integrity.

Conclusion

Integrated ATG recording is now a mature concept in the ATM industry. The initial challenges have been addressed by manufacturers such as EIZO and are no longer a barrier to its selection over traditional methods such as X protocol recording. The nature of the recording market is such that any recorded data should be unambiguous in its nature and from a passive interface, thus ensuring that it is a 100% accurate representation of the scenario at any given point in time. As more data is generated, systems are required that allow the data to be managed efficiently while maintaining ease of access for reproduction. Access to data in the ATM recording environment will change in alignment with how we access audio and video content in our day-to-day lives. Streaming from file repositories will become the norm and users will not need to manage files to enable access.

As a visual technology company, EIZO offers a range of monitors, graphics cards, as well as recording and streaming solutions to the ATM market, which continues to expand with a growing understanding of its mission-critical needs. EIZO offers complete ATC video data management from start to finish, with the technical background to build even further on these solutions for the future.