Fully Integrated Digital Imaging
In an Access Control and Security System

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Abstract

Traditional analogue Closed Circuit Television (CCTV) systems provide an effective means of monitoring and alarm verification. However, for some facilities the cost of both equipment and installation for these systems is prohibitive. These systems also suffer from "information overload" – an operator cannot watch every CCTV monitor all the time, and finding the exact frames you want on videotape can take a considerable amount of time.

Recent developments in Digital Signal Processors (DSPs) and "camera on a chip" image sensors mean that it is now possible to develop a totally digital intelligent camera that overcomes some of the deficiencies of standard analogue CCTV systems. This paper describes a camera under development (patents pending) which takes advantage of these technology developments to provide a digital imaging system that is fully integrated with an access control and security monitoring system.

Keywords*: security camera, digital signal processor, integration, image compression.*

1. Introduction

Cardax (International) Ltd. develops and manufactures access control and security monitoring systems. These systems are often installed as part of an overall security system that includes a Closed Circuit Television (CCTV) system. Traditionally access control and security monitoring systems and the CCTV system have either not been integrated at all, or have been integrated loosely using one or more of the following techniques –

- On-screen video – Live video from a CCTV camera (usually routed via a switcher) is displayed on-screen using a video capture card.
- On-screen control of the CCTV system – The CCTV switcher manufacturer's software for controlling the CCTV switcher(s) is run on the same Personal Computer (PC) as the operator uses to monitor the access control and security monitoring system.
- Automatic control of CCTV switchers – The access control and security monitoring system communicates with the CCTV switcher(s) and switches cameras to monitors when alarms occur, or when an operator processes an alarm.

The CardaxFT system overcomes the deficiencies of the above approaches by using a digital camera that is totally integrated with the access control and security monitoring system.

This digital camera takes advantage of recent developments in Digital Signal Processors (DSPs) and "camera on a chip" image sensors [1] to provide a totally digital intelligent camera.

The digital camera is treated as simply another field device, like a card reader or input/output board, which connects to the same RS-485 wiring used by these field devices. This total integration has several advantages –

- Reduced cost of installation. The digital cameras are connected to the system using the same CAT 5 cabling as the card readers – no expensive coaxial cable is required. Expensive camera switchers, video motion detectors or video recorders are not required.
- Alarm triggered image storage allows storage of only the images that are of interest, providing a useful alarm verification tool.

Integration with the access control and security monitoring system's alarm control means that the system's event and alarm log can be used as an index to image sequences.

This paper describes the CardaxFT access control and security monitoring system, and in particular how the CardaxFT Digital Camera fits into this system.

2. CardaxFT System

CardaxFT is an integrated access control and security monitoring system. The system is comprised of the following devices:

- A server PC that stores the main system databases.
- Workstation PCs that that are used to configure and monitor the system.
- A number of CardaxFT controllers that connect to the head-end PC over an Ethernet network using TCP/IP. The controller is powered by an Intel 32 bit processor with 4MB of RAM and 8MB of Flash memory.
- A number of field devices, including card readers, card readers with built in digital intercom, I/O boards and cameras, that connect to the controllers over a fast RS-485 serial communications link.

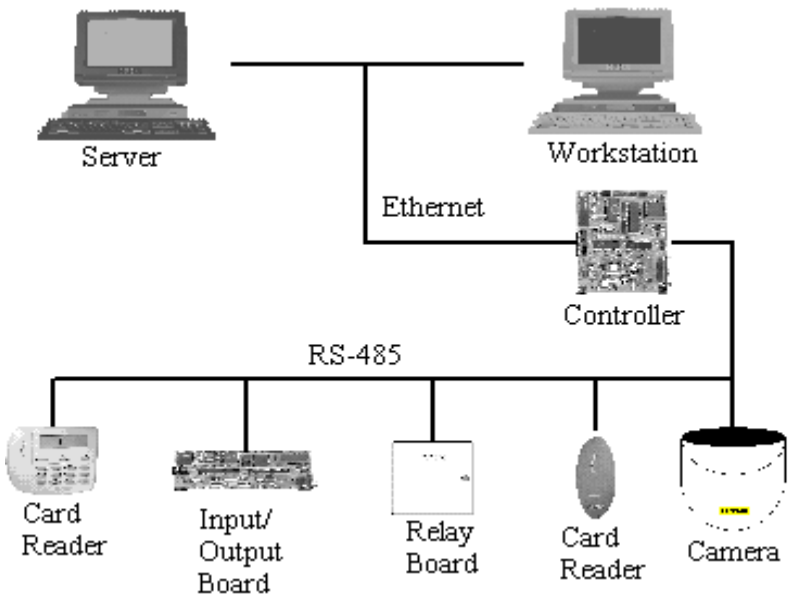

Figure 1: CardaxFT system.

The CardaxFT controllers are responsible for making access decisions and reporting events and alarms to the head-end PC. The controllers also manage the real-time multimedia links between the digital cameras or digital intercoms and the workstation(s).

3. Intelligent Camera Architecture

The CardaxFT Digital Camera comprises of three main processing blocks (see Figure 2) –

- Image acquisition - An image sensor (CMOS Active Pixel Sensor) and a microcontroller for controlling the sensor. The image sensor copies images directly into the DSP's memory.
- Image processing – A DSP for image compression, watermarking and motion detection.
- Communications – A microcontroller that provides a high speed serial connection over an RS-485 serial connection to the main controller.

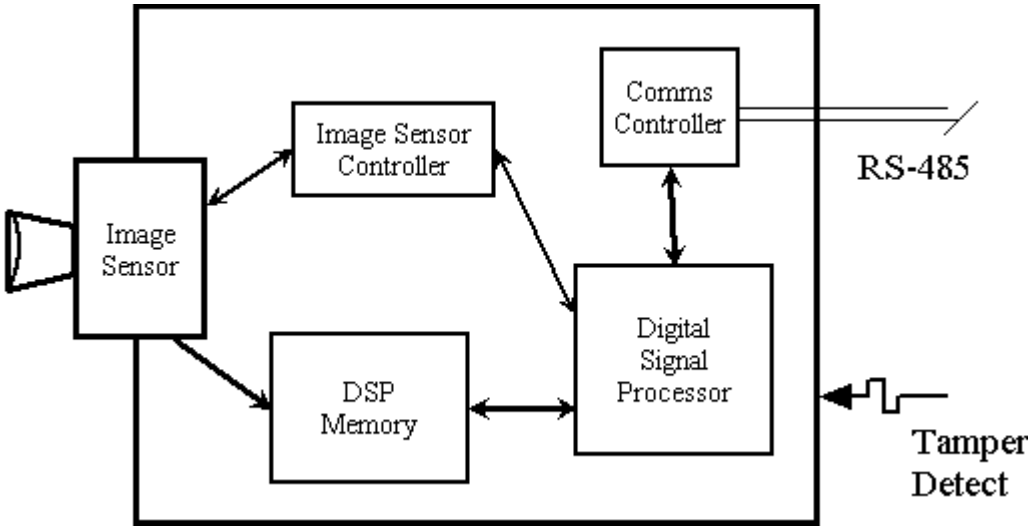

Figure 2: CardaxFT digital camera architecture.

4. Image Compression

The digital image captured by the image sensor is a 512 by 384 pixel grey scale image with one byte per pixel. This means that a full image takes 192k bytes to store. To transmit these images over the RS-485 at 2 frames per second (fps) requires that the images be compressed by a factor of at least 35:1. This image compression is performed by the DSP using an optimised implementation of the Symmetric Wavelet Transform (SWT) [2]. Post transform processing includes Wavelet Scalar Quantisation (WSQ), zero-tree construction and coding based on Sequential Baseline Coding (SBC) [3]. A final lossless entropy encoding stage is used to further compress the image prior to storage and transmission [4].

The image compression works on a single image and does not use differencing techniques to reduce the image data. There are two reasons why this approach was taken –

1. At the relatively slow frame rate being used (2 fps) the frame differences will tend to be quite large, reducing the effectiveness of a frame differencing based compression scheme.
2. Each frame can stand alone – that is, it can be decompressed and verified as a single frame with no knowledge of previous frames.

At the workstation the images are decompressed and displayed. The use of Intel's native signal processing library [5] on an MMX enabled Pentium ensures that the decompression places only a moderate load on the workstation PC.

5. Image Authentication

One of the weaknesses of a digital image is the ease with which it may be modified. This is particularly important for a security camera since the images will be stored on disk and may be required to be used as evidence in the future. The camera applies an Image Authentication Watermark (IAW) to each image – this IAW provides tamper proofing and authentication. The tamper proofing allows the detection of any changes to images that could be made by decompressing the image, editing it and then re-compressing the image. The authentication proves that the image was captured at a specific time from a specific camera. Each camera has a unique serial number, and this number is combined with the time and date stamp of the image and the serial number of the site. A digital signature is then calculated using this

unique data and the resulting signature is combined with the wavelet compression coefficients in the compressed image as a repeating pattern [6]. The IAW of a stored image can be verified by i) checking that the pattern repeats over the image and ii) verifying that the digital signature embedded in the watermark matches the camera serial number, image time and date stamp and the site serial number.

Calculation of the digital signature is done using a public key digital signature algorithm. As with most public key encryption a large number of multiplications are involved in the calculation. A key feature of a DSP is the capability to perform fast multiplications, making it an ideal processor on which to implement the digital signature algorithm [7,8].

6. Motion Detection

Up to 10 separate regions in the field of view can be configured for motion detection. The camera reports an event when motion is detected in a region. These motion events can be connected into the CardaxFT system's alarm processing in the same way as any other events monitored by the system. This allows motion alarms to be generated based on time of day or armed/disarmed state of an alarm zone.

The motion detection algorithm exploits the nature of the wavelet compression by measuring the Mean Square Error (MSE) between sequential frames using image data at the lowest level of the wavelet decomposition. The low pass wavelet filter banks effectively remove extraneous noise from the images prior to the frame differencing operation. In doing so the amount of data to be compared between the two frames is reduced by a factor of 256 in a four level decomposition which further improves the speed with which inter-frame motion can be calculated. The amount of data to be stored from the previous image is also reduced by the same factor so a full last image frame buffer is not required. Another advantage of using the wavelet decomposition to support the motion detection operation is that the decomposition is already performed as each image is compressed. The motion detection operation is co-operative with the image compression algorithm, further reducing the need for additional computation.

7. Event or Alarm Triggered Archiving of Image Sequences

Any event or alarm in the system (including detection of motion by the camera itself) can trigger the transfer of images from the camera's internal loop frame store, allowing a sequence of images from before and after an alarm event to be automatically saved. The number of images transferred is configurable, with the camera having the capacity to store approximately 60 images. The sequence of images is transferred to a PC hard disk and is indexed by the event that triggered the image transfer, allowing simple and efficient access of the images.

The system provides an effective alarm verification system by only storing image sequences when events of interest occur. When an alarm is reported by the access control and security system an operator does not have to worry about having missed the event on a CCTV monitor, but can simply select the alarm and ask the system to play back the images stored with that alarm.

8. Indexing and Storage of Image Sequences

The CardaxFT Controller keeps track of which event triggered the storage of an image sequence, so that it can include this information with the images when they are sent to the head-end PC for storage on hard disk. This head-end PC is therefore easily able to index the images by the event or alarm that caused the images to be saved.

From the operator's point of view this means that an operator can search for any event (or alarm) in the system's event log (based on the time of the event, type of event or the source of the event). Having found an event the operator can simply request to play back the image sequence associated with that event (if there are images linked to that event).

9. Comparison with Existing CCTV Systems

The CardaxFT system, with digital cameras, has a number of advantages over traditional CCTV systems. These advantages include :

- Lower cost of installation.
- Cabling. Most CCTV systems require coaxial cable to be run to each camera, whereas the CardaxFT cameras require lower cost CAT5 cable to be run form the camera to the nearest controller.
- Equipment. To effectively bring several cameras back to a group of monitors requires the use of video matrix switchers, at an added cost. Because the CardaxFT system is fully digital, and fully integrated, no separate devices are required to allow the images to switched to any operator workstation in the system. Cameras may be monitored from any Windows 95, 98 or NT PC.
- Ease of installation. The cameras connect to the same RS-485 cabling as the card readers and other field devices in the system. Cameras are likely to be needed in similar areas, or close by, to card readers, making adding a camera to the system easier.
- Secure evidence. The stored images are tamper proof and verifiable.
- Ease of finding stored image sequences after an event. Traditional CCTV systems use video cassette recorders (VCR) to archive captured video. Searching a video tape for a specific set of frames can be very time consuming and frustrating. By linking image sequences to events and alarms the CardaxFT system makes finding a specific image sequence as simple as finding a specific event or alarm.
- Remote monitoring. Especially in applications where watching live images from a camera is not a priority, the system can effectively be used on remote sites with the CardaxFT controller connected back to the central system over a Wide Area Network (WAN).
- Alarm verification. The system provides an effective alarm verification system, freeing the operator from having to continuously watch several CCTV monitors.
- Reduced image storage. The system only transfers images from the camera to hard disk when alarms or events of importance happen, greatly reducing the amount of storage required for images.

10. Conclusions and future work

The CardaxFT system with the integrated digital camera provides a cost-effective alternative to analogue CCTV systems. The CardaxFT digital camera takes advantage of new advances in image sensors and DSPs to provide this unique level of integration.

The current system provides only black and white images (grey scale) – a colour version is planned as a future development.

The digital camera has field upgradable software, allowing improvements to the image compression algorithm to be simply downloaded into the camera when available. Further work on improving the efficiency of the image decompression at the workstation is also planned.

Some research work has already been done in the area of rejecting false motion detection alarms (for example, ignoring curtains flapping in the breeze). Further work in this area is required to provide a commercial implementation. The system also provides an ideal framework for ongoing research and development in the area of face recognition as a form of access control.

Figure 3: CardaxFT digital camera

Figure 4: CardaxFT digital camera with cover removed

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