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DIGITAL SIGNAL PROCESSING IN VIDEO SURVEILLANCE

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ABSTRACT

This paper presents two principles of Digital Signal Processing (DSP) techniques in Video Surveillance technology. First, noise due to camera and quantisation process estimation which has been a persistent problem in video surveillance systems was evaluated using variance method of noise estimation. Second was the evaluation of the effects of bitrate on Peak Signal to Noise Ratio (PSNR) using search range and slice of increasing values. The simulation which was carried out using H.264/AVC-16.1 shows that small values of search range and slice produced good results for both bitrate and PSNR. Implying that search range and slice have exponential rise relationship with the average frame in motion (vector). Unlike other traditional motion estimation techniques, like H.26x, H.264/AVC is an efficient video compressor using bitrate with less computational complexity and good image quality.

INTRODUCTION

The quest for a secured life and property in both public and private areas necessitated the drive for the development of an efficient video and image processing monitory system known as video surveillance. This technology which started as an analogue tape-based system on Traditional Closed-Circuit Television (CCTV), is now one of the best tools for crime investigation and system monitoring/tracking. The application of computer system and other related digital vision systems like camera and buffers on this technology, digitised the whole process, making it easier to store and analyse data using Digital Signal Processing (DSPs) algorithms and Field Programmable Logic Array (FPGAs).

Several DSP processing techniques such as Shadows detection/suppression, motion/blob detection, video compression etc. based on quantisation, sampling, filtering among others evolved alongside with the technology. The mode of operation has however improved significantly in the resolutions of the captured images, and speed of processing among others but has maintained the same principle of capturing images using the end devices (cameras), digitising the jammed data and forwarding it to the backbone network for processing shown in Fig 1.

This paper seeks to investigate the DSP principles and algorithm in the developmental processes of video processing and surveillance, and give a practical description of how quantisation and noise estimation is implemented in video surveillance systems. Search range and slice which are sequences of macroblocks in which frames are divided in H.264/AVC were investigated. This error resilient encoder for motion video estimation technique were explored using h264avc_ver16.1.

Video Surveillance Hardware Architecture

The core of a video surveillance system is the DSP. The structure has other sub systems where a unique DSP processing technique is applied to improve the information processing.

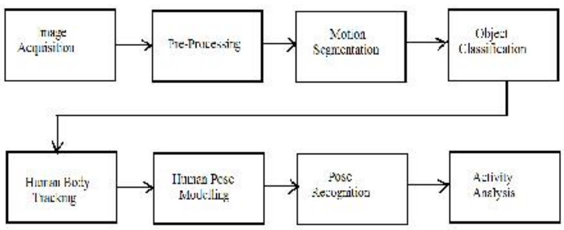

Figure 1 Block Model of a Video Surveillance System

This system in summary can handle object's entry and exit by frame differencing of detected moving object, dynamic template matching by tracking objects from frame to frame and analysing the object. The video data stream acquired by the digital camera needs to be analysed in order to extract and interpret the regions of interest. This is achieved using filters to eliminate unnecessary

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information and analyse the filtered area which will require more restrained bandwidth and lower software and hardware costs [4].

But the main work of the system starts by pre-processing the acquired data in order to enhance the quality of frames because of induced noise due to camera, illumination, reflections, quantisation process etc. [3]. The variance of this noise is handled by DSP techniques known as block smoothing-based and wavelet-based encoders by using inter-frame and intra-frame differential operation [5]. The video coding standards has developed overtime with the addition of enhanced features to support additional resolutions. Embedded video surveillance based on Advanced Video Coding (H.264/AVC) is now the current standard of multimedia processing [4]. It has evolved overtime and is widely responsible for advancement in digital and mobile television systems, videoconferencing and internet video streaming.

Blocked based DCT/DPCM Predictive coding schemes

$$\begin{pmatrix} H261:1990 \\ H.263:1995 \\ MPEG1:1991 \\ MPEG2:1994 \\ AVC/H264:2004 \end{pmatrix}$$

Object based DCT/DPCM coding $\left(MPEG4:1998\right)$

Intra-frame coded video $\begin{pmatrix} Motion-JPEG \\ JPEG2000 \end{pmatrix}$

DSP Techniques of Noise Estimation in Video Surveillance

Many noise estimation techniques have been employed over the years. Subjective evaluation has proven to be more effective because human eye is the terminal receiver of video signal. The noise introduced in video surveillance is mainly due to camera and quantisation while ignoring noise along the transmission channel.

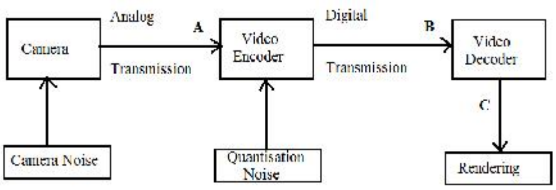

Figure 2 Video Codec and Noise Model.

This model estimates the optoelectronic and thermal electronic noise introduced in the camera in the form of independent, identically additive and stationary zero Gaussian noise.

Noise Estimation in video Camera

Noise estimation is one of the practical example of DSP principles applied in video surveillance. Noise in video camera consists of independent identically distributed additive and stationary opt-electric and thermal noise. It is usually assumed as zero mean Gaussian noise with the expression below.

$$I(i,j,n) = S(i,j,n) + N(i,j,n) \text{.......................} Eq.1$$

Where, is the original video is signal and is the noise signal with i and j representing the position of the pixel in the x and y directions respectively and n is the picture number. Noise estimation is based on the differential of noise variances of still and moving frame. For a still object, the outcome in the difference of two successive frame is a pure noise.

$$D_{still}(i,j,n) = I(i,j,n) + I(i,j,n-1)$$
$$= N(i,j,n) + N(i,j,n-1) \text{.........................} Eq.2$$

$$\pm^{2}_{still} = 2\pm^{2}_{n} \text{......................} Eq.3$$

Video is a moving picture with wide spectrum and low frequency components, the method of estimation depends on the nature of the frame. A still frame employs inter-frame estimation and a homogeneous frame uses intra frame estimation.

In real system, matching two frames to apply differential operation due to the delay of codec makes estimation of quantisation noise difficult. Standard codec like H.264, MPEG, AVS, etc. use hybrid coding method motion compensation and intra-prediction of image blocks. The result is transformed into DCT domain. The uniformly quantised coefficients of DCT is used to determine the average absolute value and the uniform quantisation step size which determine the level of distortion. The step size has a direct relation with the quantisation and the DCT average absolute values as shown in figure 3.

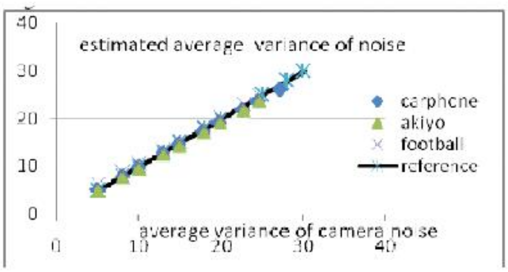

Figure 3 Camera Noise Estimation

The study of LI Jin-Cho *et al*, which investigated the motion intensity of football players, carphone and akiyo revealed that noise in images with large still areas were underestimated while those with large moving areas were overestimated.

H.24/AVC Video Coding

H.264/AVC is the current video coding standard of the International Telecommunication Union Telecommunication (ITU-T) coding standards for enhanced video compression. This coding technique was investigated in MATLAB using two parameters to monitor how compression sequence affected the frame performance. Two parameters that were selected to analyse the performance were 'search range' and 'Slice' and observed overall performance of frames that is to be encoded according to the H.24/AVC architecture in figure 4.

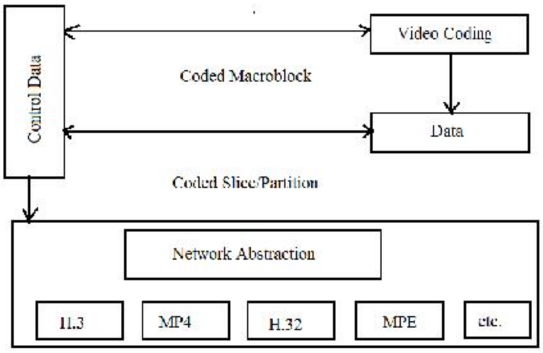

Figure 4: Structure of H.264/AVC Encoder.

It is a hybrid video coding approach where each coded picture is represented in block shaped units of associated luma and chroma samples known as macroblocks. This coded sequence of picture consisting of two interleaved fields is what makes up the coded video sequence.

Search Range

In the experiment, values (5, 10, 15, 20, 25, and 30) were assigned to 'search range' and both QPI slice and QPP slice were assigned a value of '10' in order to encode 64 frames. The MATLAB program was executed for various values of QPI slice and QPP slice (15, 20, 25, 30, and 40). The results obtained was used to investigate the relationship between bitrate and Peak Signal to Noise Ratio (PSNR) as shown in figure 5.

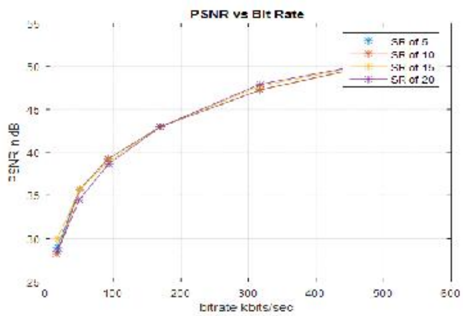

Figure 5 PSNR and Bit Rate

The results show that search range value of 5 recorded good performance when compared to other values. When the right choice of parameters is made during an encoding process, there will be a consistency in the frame quality thereby facilitating the quality of encoded image. The encoding process for 64 frames takes significant amount of time to be encoded which means that the efficiency of encoded information depends on size of frame.

Slice

Similarly, values (1, 2, and 3) were assigned to slice range, while QPI and QPP values were unchanged. The performance of the encoded frame in terms of PSNR and Bitrate is shown in figure 6

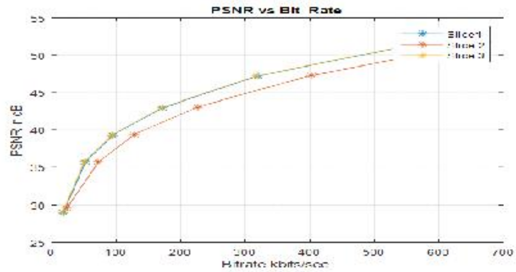

Figure 6 PSNR and Bit Rate

The results depicted a similar response to the search range. The slice value of 1 required less bits rate when compared to slice 2 as it required more bits rate for the same PSNR value.

CONCLUSION

DSP in Video and video surveillance processing techniques such as detection, compression, recording, and optimization etc. is based on various DSP principles. The improvements in both software and hardware like chip design which has enabled integrated camera recording, video analytics and multi streaming programming architecture known as codec can be attributed to DSP. H.264/AVC is one of the latest standards in video encoding that supports enhanced efficiency and diversity in motion estimation and error correction.

DSP has also brought about video surveillance devices being produced in small sizes with high optimisation, having low power consumption, being fast and scalable. It is regarded as the core of a video surveillance system and has been the success behind the various technology advancement of vision and security systems like automatic people counting.

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