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For Underwater Channel Implementation of H.264 Based Real Time Video Compression

KEYWORDS: OpenCV, MATLAB

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ABSTRACT *Underwater acoustic channel have a greater challenge because of its low data rate constraint which makes its difficult for real time video compression algorithm using low complexity devices. In order to transmit a good quality video, in real time underwater embedded system, compression schemes with higher compression ratio and much less time complexity are required. For underwater acoustic channel, a H.264/AVC based real-time encoder implementation on an embedded system. The proposed system results from balanced selection of software and hardware modules for the encoder. This is achieved by proper selection of motion estimation and quantization in software part and hardware accelerator for motion estimation to achieve the requirements of the target applications. Performance of the proposed encoder is evaluated in Embest Devkit 8500D implemented using OpenCV for Video acquisition and MATLAB for video processing. The methodology is tested to give a compression ratio of 210:1 and PSNR of 41.37dB.*

INTRODUCTION

In modern science robust, high speed communication is highly developed, but still there is some technical limitation in the underwater applications. Implementation of robust, high speed underwater wireless communication is currently an area of active research. Underwater video transmission is one of the major applications of underwater wireless communication. Underwater video transmission is used in many fields like underwater defence applications, autonomous underwater vehicles (AUV), oil and gas surveys, underwater pipe inspection, real-time monitoring of marine life and reef, entertainment, education and more.

There are two major ways of underwater communication. One is using electromagnetic waves and another is using acoustic waves. In air, RF communications operate over long distances at high data rates. But due to the high absorption of electromagnetic signals at radio frequencies it is not feasible in water. Using electromagnetic waves recent research shows promising results in the blue-green range of the visible spectrum. By maintaining accurate optical channel between transmitter and receiver that can be achieve. Optical fibers are used for high data rate links in fixed underwater applications like telecommunication cables but are too expensive for use in most science applications. Maintaining accurate optical channel between transmitter and receiver makes mobile platforms impractical to be used in such applications. Other major drawbacks are limitation of short distance coverage (<100m) and scattering of optical waves.

On the other hand, due to high density of water acoustic waves travel through water exceptionally well. Since the speed of sound is several times lower than the speed of light, the data rate is much lesser (typical data rates ranges from 20 to 50 Kb/s) than that of light wave communication. Acoustic modems generally operate over moderate ranges and potentially higher rates for some specialized, short range systems. At these speeds, to transfer large data files take a long time period and real-time video transmission is not feasible. Data rate as a function of power consumption is the primary issue related to underwater wireless communication.

TABLE – 1
PERFORMANCE COMPARISON

Telemetry Method	Range	Data Rate	Efficiency
Acoustic	Several km	1 Kbps	100 bits/Joule
Optical	100 meters	1 Mbps	30,000 bits/ Joule

In acoustic transmission, the data rate will always be less than the equivalent optical transmission solution. Currently, these issues limit the retrieval of real-time data from ocean sensors and usually require an instrument to be recovered in order to download the full resolution data set. This limitation brings about the need for compression when attempting to bandwidth. It is important to find a powerful compression technique that can reduce the bit rate requirements for real-time underwater video transmissions.

This necessitates the coding schemes with high compression ratio, but it leads to high computational requirements. In the literature several techniques are proposed on hardware accelerators for H.264/AVC to perform different operations. These techniques are only intended to implement the algorithm and to execute it within the hardware, leaving behind the specific purpose of the particular hardware module. The most complex part of the encoding is motion estimation, some suitable hardware accelerator are needs to be used in this part. In this methodology, hardware and software components are designed to ensure that they together achieve required target application goals and performance. In software part, to increase the compression ratio encoder with uneven multi-hexagonal (UMH) search algorithm for motion estimation and Trellis 1 quantization algorithms are used. In hardware section, a multi-core processor (TI DM3730 DaVinci Digital Media Processor) with a graphic accelerator is used to speed up the compres-

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sion process. Further, to balance between the developed software and the designed hardware, ten frames at a time accessed from the video sequence. This is done mainly to cope up with the RAM limitation of the hardware. With this combination of hardware and software, promising results are obtained for the target application.

LITERATURE SURVEY

Since the early 1990s, when the technology was in its infancy, international video coding standards – H.261, MPEG-1, MPEG-2 / H.262 , H.263 , and MPEG-4 (Part 2) – have been the engines behind the commercial success of digital video compression. They had played pivotal roles in spreading the technology by providing the power of interoperability among products developed by different manufacturers, while at the same time it provides enough flexibility for ingenuity in optimizing and molding the technology to fit a given application and making the cost-performance trade-offs best suited to particular requirements. A Thesis "A STUDY OF MPEG-2 AND H.264 VIDEO CODING" submitted by Michael Igarta to the Faculty of Purdue Univers. This thesis presents an overview of the differences between the MPEG-2 standard and the recently finalized H.264 video compression standard.

The roots of development of H.264/AVC standard lie in the ITU-T's H.26L project which was initiated by the Video Coding Experts Group (VCEG). ITU-T and ISO/IEC both agreed to join forces together to jointly develop the next generation of video coding standard and consider H.26L project as the starting point. A Joint Video Team (JVT) consisting of experts from VCEG and MPEG, was formed with the goal of completing the technical development of the standard by 2003. H.264 is the result of a joint project between the ITU-T's Video Coding Experts Group and the ISO/IEC Moving Picture Experts Group (MPEG). ITU-T is the sector that coordinates telecommunications standards on behalf of the International Telecommunication Union. ISO stands for International Organization for Standardization and IEC stands for International Electrotechnical Commission, which oversees standards for all electrical, electronic and related technologies. H.264 is the name used by ITU-T, while ISO/IEC has named it MPEG-4 Part 10/AVC since it is presented as a new part in its MPEG-4 suite. H.264 also has the flexibility to support a wide variety of applications with very different bit rate requirements [1]. July 2003, Thomas Wiegand, Gisle Bjøntegaard, Gary J. Sullivan and Ajay Luthra published paper "*Overview of the H.264/AVC Video Coding Standard*", describes an overview of the outlines the history of the standardization process and technical features of H.264/AVC and also describes profiles and applications for the standard[2].

In 2007, Loren Merritt and Rahul Vanam in paper "*IMPROVED RATE CONTROL AND MOTION ESTIMATION FOR H.264 ENCODER*", explained motion estimation and rate control in x264, an open source H.264/AVC encoder. And also compare the rate control methods of x264 with the JM reference encoder and show that approach performs well in both PSNR and bitrate[3]. In motion estimation, describe implementation of initialization and show that it improves PSNR. During January 2005 to November 2007, JVT was working on an extension of H.264/AVC standard towards scalability by an Annex (G) which called as Scalable Video Coding (SVC).

The latest video compression standard H.264 is also refered as MPEG-4 Part 10/AVC (Advanced Video Coding). H.264 is expected to become the popular video standard in the upcoming years. Now-a-days, H.264 is an open and licensed standard that supports the most efficient video compression techniques available. Bharathi S.H., S. Ramachandran and K. Nagabhushana Raju had been published paper "*Implementation of Intrapredictions, Transform, Quantization and CAVLC for H.264 Video Encoder*", on 2011. In these paper, the algorithm for all the nine modes of intraprediction is presented by which the compression is achieved without sacrificing the quality of the reconstructed picture[4]. For development of new network access technologies like cable modem, xDSL, and UMTS(Universal Mobile Telecommunication System) created demand for the video coding standard H.264.

VIDEO COMPRESSION

Video compression is process in which reducing and removing redundant video data so that a digital video file can be effectively sent and stored. In these process an algorithm is apply to the source video to create a compressed file that is ready for transmission or storage. To produce the compressed file, an inverse algorithm is applied to play a video that shows virtually the same content as the original source video. Latency is the time required to compress, send, decompress and display a file. Due to more advanced the compression algorithm gets the higher the latency for the same processing power.

A video codec (encoder/decoder) is a pair of algorithms that works together. Video codecs that implement different standards are normally not compatible with each other. Video content that is compressed using one standard cannot be decompressed with a different standard. For example, an MPEG-4 Part 2 decoder will not works with an H.264 encoder. Simply its occurred because one algorithm cannot correctly decode the output from another algorithm but it is possible to implement many different algorithms in the same hardware and software, which would then enable multiple formats to be compressed.

Different video compression standards utilize different methods of reducing data, and therefore, results differ in latency, bit rate, and quality. Results from encoders that use the same compression standard may also vary because an encoder designer can choose to implement different sets of tools defined by a standard. It is possible to make different implementations as long as the output of an encoder conforms to a standard's format and decoder. This is advantageous because of different implementations have different goals and budget. For mastering optical media, Professional non-real-time software encoders should have the option of being able to deliver better encoded video than a real-time hardware encoder for video conferencing. Therefore a given standard, cannot guarantee a given bit rate or quality. The performance of a standard cannot be properly compare with any other standard, or even other implementations of the same standard, without defining how it is implemented.

In order to decode a compliant bit stream unlike an encoder, a decoder must implement all the required parts of a standard. This is because a standard specifies exactly how a decompression algorithm should restore each and every bit of a compressed video.

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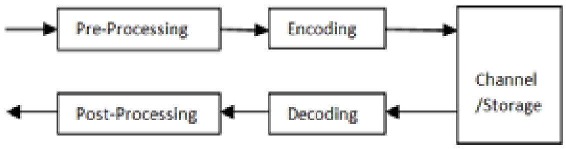

Figure 1: Scope of video coding standardization

ENCODER DESIGN

Now-a-days H.264 standard is widely used because of its high quality and compression ratio in high bitrate channel. The H.264 standard uses different modes of prediction and motion compensation techniques. This increases the computational complexity of the H.264 standard. Hence H.264/MPEG-4 standard is not suitable for low bitrate applications. To overcome this problem, there is a need to select components and proper algorithms for the encoder and make it possible to implement on the encoder for low bitrate channel. An encoder based on H.264 standard is developed for low data rate real time video compression.

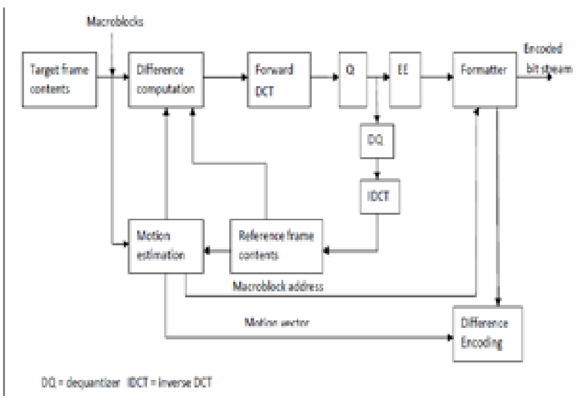

Figure 2: Block diagram of the proposed H.264 based encoder

Prediction, Transform, Quantization (Q), motion estimation and entropy (EE) are the main blocks of the encoder. When raw frame contents are fed to the encoder it initially gets converted to frames for further process. In prediction part, Spatial and temporal redundancies are exploited to greatly reduce the amount of data to be encoded. Prediction can be of intra or inter type. Intra prediction is for the generation of I frames and the later one is for multi frame generation. Further by applying mathematical techniques like DCT (Discrete cosine transform) transform and quantization expresses energy of the frames in the form of matrix. By keeping reference frames motion estimation and compensation uses already encoded to reduce the prediction errors.

Entropy coding is the final stage of a process. Entropy coding techniques like context-adaptive variable-length coding (CAVLC) and content-adaptive binary arithmetic coding (CABAC) has been improved by using H.264. Both entropy coding techniques are lossless, CAVLC takes advantage of quantized block to find out highest non-zero coefficients by scanning in zigzag direction whereas as CABAC selects probability models based on elements context. In the encoder, Motion estimation, Rate control and Quantization are the main blocks that decides the compression efficiency and data rate.

Motion Estimation

Motion estimation is the most time consuming and complex part of H.264. It offers better performance for low computational power devices, if this complexity and time consumption is reduced. In literature, there are several motion estimation algorithms available. For example, diamond search, successive elimination exhaustive search and hexagon search algorithms.

Successive Elimination Exhaustive search algorithm is a brute-force search algorithm which checks every block available to find the closest match to the block under consideration. When quality is the most important factor in the motion estimation process this algorithm is used. The Diamond Search (DS) algorithm performs block-matching motion estimation by employing a square shaped search pattern in four directions around the checking point under consideration: up, down, left and right. This algorithm is used when search speed takes priority over image quality. Uneven multi-hexagonal (UMH) search algorithm which is a combination of the diamond search and the hexagon search algorithms is used. The combination of is utilized in order to perform computations faster and diamond search and the hexagon search algorithms obtain reliable motion vectors. This can be done by applying the diamond search algorithm first, then using the hexagon search algorithm. The scheme uses these two algorithms diamond search and the hexagon search algorithms alternatively until a terminating condition is reached. The motion vectors found by the algorithm are reliable and suitable for real-time applications due to lower computations required in comparison with schemes that rely only on either the diamond search or the hexagon search. Early termination reduces the time consumption along with UMH greatly.

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3		3		3	2	1	0	1	2	3		3		3
					3	2	1	2	3					
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Figure 3: Search approach for early termination decision in Uneven Multi-Hexagon search

Figure 3 shows the search pattern for the early termination decision in Uneven Multi-Hexagon. Where Diamond search of radius one is labeled as '1', diamond search of radius two is labeled as '2', and octagon search of radius two are labeled as '3'.

Rate Control

Rate control is process of controlling the output bitrate by controlling the quantization parameters. It is mostly empirical. For real time operations, one-pass scheme is used for real time operations. The one-pass method involves using faster motion estimation method on a half-resolution version of the frames and used the Sum of Absolute Had-

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amard Transformed Differences. The quick processing is required for real-time implementation.

Macroblock Mode Decision and Quantization
In macroblock mode decision, 8x8 blocks for both inter-predictionand intra-predictions are used for real time compression. Two early terminations are used to speed up mode decision and for the final refinement. After selecting a motion vector and macroblock type (and during each RD evaluation) the residual is computed, which is the DCT (Discrete cosine transform) of difference between the input frame and the intra- predicted or inter-predicted macroblock.

For representing the DCT integer values coefficients are selected and this process is known as quantization. To discard insignificant information quantization is used. It basically converts each real DCT coefficient to an integer by scaling it by a factor and then discarding the digits after the decimal point. For each coefficient, a scaling factor is chosen in such a way that there is no perceptible change even after discarding digits after the decimal point.

TABLE – 2
PERFORMANCE COMPARISON

Motion Estimation	UMH
Block Size (Intra & Inter Prediction)	8x8
GOP	IPBBPBBIBB
Handmard Transform	Used
Early Termination	Used
Entropy Coding	CAVLC
Quantion	Trellis
Video Size	176 x144

In the TABLE 2, the configuration parameters of the encoder used is summarized. Other parameters which are not given in the table 6.1 are considered same as that of the standard H.264/MPEG-4, as they also support real time video compression scheme.

PERFORMANCE EVALUATION PARAMETERS
On a raw underwater video sequence the compression scheme has been tested in Embest Devkit 8500D. H.264 based encoder is developed then used in the compression process.

Peak Signal-to-Noise Ratio (PSNR)
Peak Signal-to-Noise Ratio is defined as the ratio between the maximum possible power of the signal, to the power of the corrupting noise that affects the fidelity of its representation. It is expressed in terms of logarithmic decibel scale [5]. With respect to video compression, the PSNR is defined via the Mean Squared Error, as expressed in eqn (1) and (2).

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{i=0}^{n-1}[I(i,j) - K(i,j)]^2 \quad -(1)$$

$$PNSR = 10.\log_{10}\left(\frac{max_I^{\,2}}{MSE}\right)\text{dB} \quad -(2)$$

Where, I(i,j) is the 2-dimensional vector equivalent of compressed data and K(i,j) is the 2-dimensional vector equivalent of uncompressed data.

Compression Ratio
Compression ratio is used to quantify the reduction in data representation size produced by a data compression algorithm. It is defined as the ratio of the uncompressed file size to the compressed file size as expressed in following equation[5].

Frames Per Second (FPS)
Frames per second is the rate (frequency) at which unique consecutive frames are produced by an imaging device. Human eye can process on 10 to 12 separate frames per second. It is preferred to record at more than 15 FPS for better quality and strain less vision of a video. Thus, it is ensured that the required FPS achieved using proposed encoder.

For ex. consider sample raw video sequence of size 176x14 taken from an underwater video camera is used as the test sequence for the evaluation, snapshots of 561th frame as shown in FIGURE 4. In FIGURE 4, Only slight variation in the quality of the compressed video can be observed which shows the efficiency of the encoder.

TABLE - 3
PERFORMANCE MEASUREMENT RESULT FOR UNDERWATER VIDEO SEQUENCE

Frame count	Video duration (sec)	Time taken to process one frame (ms)	Compression				PNSR (db)	Compression Speed (frames/ sec)
			Uncompression (KB)	Compression (KB)	Ratio	Time (sec)		
1950	115	57.14	73865	353	210:1	111.42	41.37	17.5

Fig. 3: Snapshots of video frames used for performance evaluation: (a) Uncompressed (b) Compressed

Figure 4: Snapshots of video frames used for performance evaluation
TABLE 3 shows performance of the encoder. Data rate achieved is in the required range which is 37.41 Kb/s. The result of implementation shows a compression ratio of 210:1 and a PSNR of 41.37 dB which is the requirements of underwater acoustic channel for real-time application. The compression speed is 17.5 fps achieved using Embest Devkit which lies within the acceptable range for video encoding. However the compression speed of the algorithm depends on the hardware specifications.

ADVANTAGE DISADVANTAGE AND APPLICATIONS OF H.264
Advantage
H.264 delivers on its goals of supporting designed to ad-

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dress several weaknesses in previous video compression standards:

Exact match decoding, which defines exactly how numerical calculations are to be made by an encoder and a decoder to avoid errors from accumulating

Implementations that deliver an average bit rate reduction of 50%, given a fixed video quality compared with any other video standard

Low latency capabilities

Better quality for higher latency

Error robustness

Straightforward syntax specification that simplifies implementations

Its provides the balance between the coding efficiency, price and implementation complexity

A standard was created to improve coding efficiency such that coding efficiency factor increases at least by two (on average) over MPEG-2, while keeping the cost within an acceptable range.

It is very easy to integrate

Its covers a wide range of image formats

Disadvantage
H.264/AVC is most widely used video coding standard regardless of some disadvantages which are as follows:

Its requires more time coding and

Somewhat Licensing agreements are complicated

Low resiliency to channel error.

Applications of H.264
The H.264 video format has a very broad application range as H.264 encoder can select from a wide variety of compression tools that covers all forms of digital compressed video from low bit-rate Internet streaming applications to HDTV broadcast and Digital Cinema applications with nearly lossless coding. H.264 offers greater flexibility in terms of compression options and transmission support and also improved its compression performance. The H.264 standard provides integrated support for transmission or storage and including a packetized compressed format and features which help to minimize the effect of transmission errors. H.264/AVC standard is being adopted for an increasing range of applications, including following applications:

High Definition DVDs

Multimedia mailing

Remote video surveillance

Digital subscriber line video services and Direct broadcast satellite video service

Apple products including iPod video, iTunes video downloads and MacOS

NATO and US DoD video applications

Mobile TV broadcasting

Internet video

Cable TV on optical networks and copper

Cable modem, Digital terrestrial television broadcasting

Interactive storage media

Multimedia services over packet networks

Real-time conversational services (videoconferencing etc.)

Serial storage media

CONCLUSIONS
H.264 puts a huge step forward in video compression technology. Now-a-days, H.264 becomes the most powerful and state-of-the-art standard. It offers techniques that enable better compression efficiencies due to more accurate prediction capabilities, coding efficiency and also improved resilience to errors. H.264/AVC provides new possibilities for creating better video encoders that enable higher frame rates higher quality video streams and more resolutions at maintained bit rates (compared with previous standards) or provides the same quality video at lower bit rates.

Real time underwater video compression scheme for low bit rate underwater acoustic channel is studied. The developed encoder is implemented on Embest Devkit 8500D and its performance is evaluated. Thus, the results of the evaluation show that the algorithm used is suitable for real time applications, due to its high compression ratio of 210:1, PSNR of 41.37 dB and processing speed of 17.5 FPS.

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