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Objective analysis of HEVC (h.265) compressed FMRI Images

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ABSTRACT

Medical imaging and lossless compression are very critical but widely used in telemedicine area. But due to its critical nature a substantial lossless image compression for medical modalities e.g. CT, PET MRI or FMRI is required. This paper presents the compression of 4D-FMRI images with new codec i.e. HEVC and its objective analysis with uncompressed modality. The Simulation results show that the better compression ratio and significant improvement in APSNR, SSIM & MSE.

Keywords: FMRI, HEVC, objective analysis, lossless compression, medical images.

1. INTRODUCTION

Medical imaging having tremendous growth in acquisition technology ranging from 1tesla to 7 tesla. It also enables the filmless storage and archiving of imaging data which can be used for analysis, reprint or processing. An electronic picture archiving and communication systems (PACS) have been developed to provide efficient and economical storage, rapid retrieval of images, access to images acquired with multiple modalities, and simultaneous access at multiple sites [1]. It has tremendous possibilities as compared to previously known techniques and systems of image archiving as it is filmless and digital. So that it is easy to store, move or communicate to far distance using the internet etc. As the technology grown and the population increases the amount of data increases day by day. High resolution imaging as 4K image acquisition, high definition medical imaging of Computer Tomography (CT), functional medical resonance imaging (FMRI) (1 Tesla to 7 Tesla) tuning the data size from few MB's to some GB's, so that it is mandatory to undergo compression before or after archiving and communicating. Compression of images and video is a fascinating area, where various transforms, coding techniques or filters can be applied and the results can obtain accordingly. This compression may be lossy or lossless depending upon the sacrificing criteria. Either the compression ratio or the information of images or videos anyone can affect drastically. Earlier medical image compression was not the day to day practice for researchers to facilitate doctors, surgeons or academic professionals. But the telemedicine creates a dimension for researchers to think of this new area of smart life and provide ease to doctors or surgeons to produce a second opinion to observe the image or operate from a very long distance. The various medical imaging modalities e.g. Computer tomography (CT), medical resonance imaging (MRI) or functional medical resonance imaging (FMRI) is available, but compressing the medical images, where the information is the critical criteria which cannot be sacrificed, hence the lossless compression of medical images is required.

The High efficiency video coding (HEVC) [2-5] is also known as H.265, is an emerging advancement in video coding standard developed by the Joint Collaborative Team on Video Coding (JCT-VC) of ITU-T.

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This belongs to h. 26x family and its predecessor is h. 264 which is also known as Advance video coding (AVC) [3][7-15]. Its First edition was finalized in January 2013. This video project is further extended to support several other application scenarios which include anextended range with enhanced precision & colour format, scalable video recording & multi-view video coding [3] [4]. With the advancements in digital video coding used in thesmart phone, digital TVs, adigital camera the demand for improved video compression performance was increasing due to large picture resolution & better video acquisition and video quality. So that's new and substantial video coding technique is required with better coding efficiency for bit rate saving and better PSNR.Today's scenario of digital video streaming & broadcasting, digital cinema, teleconferencing, video sharing on social networking sites, Video on demand (VoD), Direct to home (DTH) etc. are the thrust areas of innovation and application. Digital videos encompass with several processing stages before they reach to end users. That's why degradation in the quality of image and videos may occur. The evaluation of video plays an important role to maintain the desired quality of Services (QoS). Video quality evaluation techniques can be categories into objective and subjective methods. In thesubjective method the subject i.e. the viewer rates the quality of theimage in Image Quality Assessment (IQA) or video in the Video Quality Assessment (VQA) respectively [28] [29]. The rating of content (Image or video) may be done by the subject with their perception. In the case of medical images or videos surgeons, medico legal expert may rate the content. Or may be groups of experts and agroup of non-experts of medical background. But in the objective IQA or VQA the content encompasses the parametric evaluation of Image or videos by mathematical algorithms. The parameters may like Peak-Signal-to-Noise-Ratio PSNR (APSNR, OPSNR or VSNR), Mean squarederror (MSE) or SSIM [32] etc. The medical image or video quality evaluation is critical as these may contain the sensitive information within. Any processing of images or videos at any stage may affect the critical information, so that the compression must be lossless. The quality evaluation may have both stages objective and subjective as per requirements. In this proposed work the compression of FMRI is done with HEVC encoder and quality analysis done by objective analysis. The compression with HEVC and uncompressed data [17-32].

The remainder of this paper is organized as follows: Section II describes the HEVC features & prediction methods. Section IIISimulation results and objective analysisfollowed by conclusion in section IV.

2. HEVC FEATURES & PREDICTION METHODS

A video project of International telecommunication union –Telecom, (ITU-T) Video Coding Expert Group (VCEG) & the ISO/IEC Moving Picture Expert Group (MPEG) standardization organization collaborate to form a team on video codes called as a Joint Collaborative Team on Video Codes (JCT-VC) [12, 20, 24]. Its First edition was finalized in January 2013. This video project is further extended to support several other application scenarios which include anextended range with enhanced precision &colour format, scalable video recording & multi-view video coding [12]. With the advancements in digital video coding used in thesmart phone, digital TVs, adigital camera the demand for improved video compression performance was increasing due to large picture resolution & better video quality. So that's new and substantial video coding technique is required with better coding efficiency, bit rate saving and better PSNR [14]. HEVC is based on a hybrid block based motion compensated transform coding architecture. The basic unit for compression is termed coding tree unit (CTU). Each CTU may contain one coding unit (CU) or recursive split into four smaller CU units until the predefined minimum CU size is reached. HEVC includes theblock structure, coding technologies, namely CTU, CU, CTB, CB, PB and TB [25].

The input video signal splits into CTUs and the consecutive block CTB, CU, CB, PB and TB. The Inter or Intra mode can be selected as per provision. Frame rate CU size, etc. Can be changed in the configuration provided in JCT-VC reference manual [12, 13, 25]. The Context Adaptive Binary Arithmetic Coding (CABAC) scheme is same as H.264 or Advanced video coding scheme (AVC)[7-10][14-17] which is thepredecessor of HEVC [12, 13, 19]. The entropy coding is the function of this block.

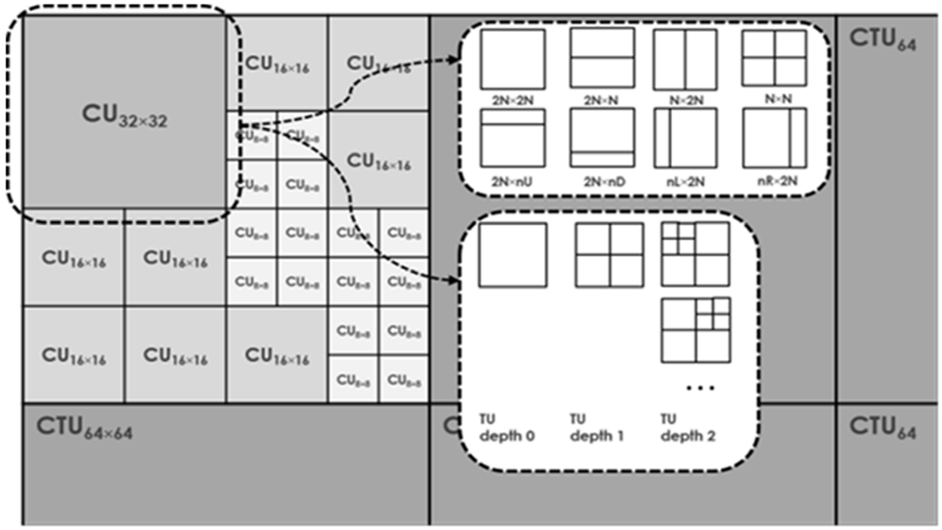
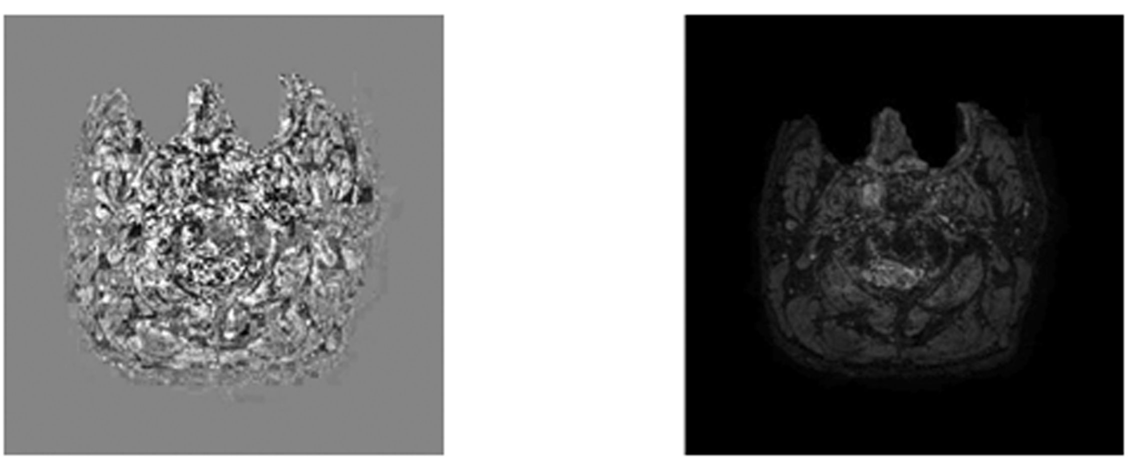


Figure 1: Block structure in HEVC [7]

3. SIMULATION RESULTS AND OBJECTIVE ANALYSIS

The experimental setup carried by 1.5 GHz 64 bit Centrino core 2duo processor, 1GB NVIDIA dedicated graphic card and 3 GB DDR-II RAM, Microsoft visual studio 2010 professional edition for HEVC is

(a) FMRI Image **(b) Predicted Image** **(c) Prediction blocks**



(d) Residual Image **(e) Final Decoded image**

Figure 2: (a) FMRI Image, (b) Predicted image (c) Prediction blocks (d) Residual image and (e) Final decoded FMRI image.

encoding and decoding. Elecard StreamEye Studio and CodecVisa for analysis along with MATLAB 2013a for graphical representation. The results show graphs of uncompressed FMRI images and compressed FMRI images by HEVC encoder. Quality evaluation is based on objective analysis parameter may be as follows (but not limited to):

In the first image Figure 2 (a) FMRI image is splitted into the CTU, CB and PB, in (b) INTRA predicted FMRI image, image in (c) showing the predicted image clearly showing the various units and blocks, image (d) is residual image of image and predicted image and in (e) the final decoded image.

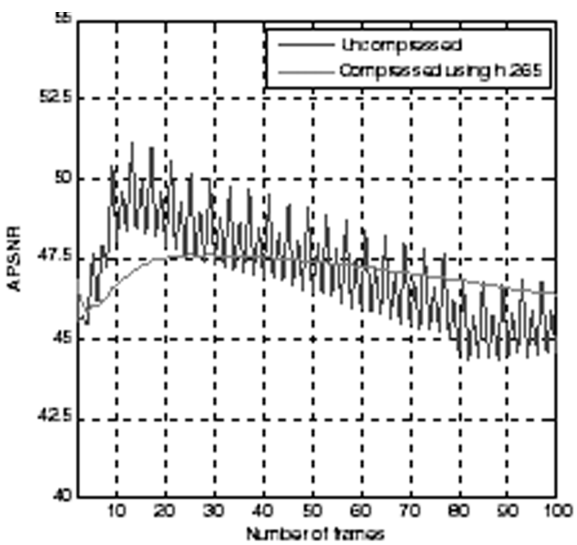
Table 1
Objective Image Quality Metrics used in the Tests[28]

Sr No	*Parameter*	*Defining equation*	*Feature considered*
1	CR	$CR = \frac{Output\ file\ size\ (bytes)}{Input\ file\ size\ (bytes)}$	This is the basic metrics often used to evaluate the performance of compression by computing the ratio of the volumeof thecompressed and uncompressed volume of image/video.
2	PSNR	$PSNR = \frac{10.\log(2^B - 1)^2}{MSE}$	It is the ratio between the maximum possible power and the power of corrupting noise which affect the faithful reproduction of the image or video. Due to a wide variety of signal range, it is expressed on the decibel scale. (B = Bit depth)
3	SSIM[32]	$SSIM = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)}$	SSIM Index is based on measuring of three components (luminance similarity, contrast similarity, and structural similarity) and combining them into result value. SSIM should be nearly equal to 1 in the ideal case, in the test it should nearly equal to 1. Where C_1 = 0. 01, C_2 = 0. 03
4	MSE	$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\left[I(i,j) - K(i,j)\right]^2$	MSE is the mean squared error this should as less as possible.
5	NQI	$Q = \frac{4\sigma_{xy}xy}{(\sigma_x^2 + \sigma_y^2)\left[(\bar{x})^2 + (\bar{y})^2\right]}$	New Quality Index, Range is [-1,1] where value 1 is the highest and is achieved if and only if the source and tested images are the same.
6	VQM	$VQM_p = \frac{1}{e^{0.1701*(PSNR-25.6675)}}, 10 \le PSNR \le 55$	VQM means Video Quality Matrixfor $10 \le PSNR \le 55$
7	MSAD	$d(X,Y) = \frac{\sum_{i=1 j=1}^{mn} \left\|X_{i,j} - Y_{i,j}\right\|}{mn}$	The value of this metric is the mean absolute difference of the colour components in the correspondent points of the image. This metric is used for testing codecs and filters.
8	Delta	$d(X,Y) = \frac{\sum_{i=1 j=1}^{mn} (X_{i,j} - Y_{i,j})}{mn}$	The value of this metric is the mean difference of the colour components in the correspondent points of the image. This metric is used for testing codecs and filters.

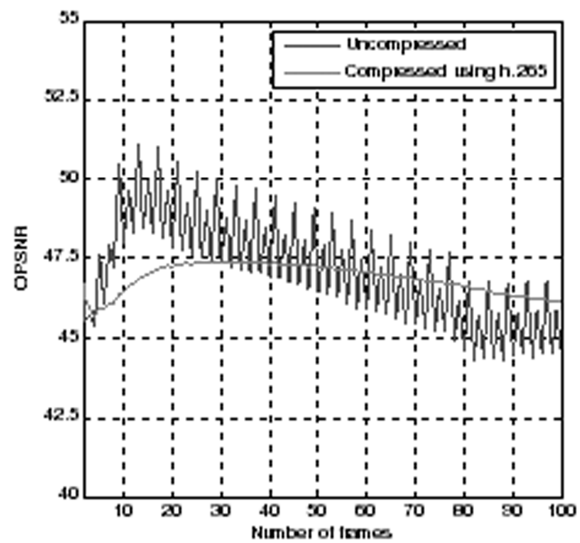
(*contd... Table 1*)

Sr No	*Parameter*	*Defining equation*	*Feature considered*
9	Bitrate(b/s)	$Bitrate\left(\frac{b}{s}\right)=\frac{Compressed\ sequence\ size}{Length\ of\ sequence}$ $Bitrate\left(\frac{b}{s}\right)=\frac{8\left(\frac{bit}{byte}\right)\times size\left(bytes\right)}{length(\mathrm{s})}$	The bit rate (R) of a bit-stream is calculated by averaging the total number of bits in the bit-stream by the length of the bit-stream measured in seconds. The results are usually measured inkilobits-per-second (Kbits/s) or megabits-per-second (Mbits/s).

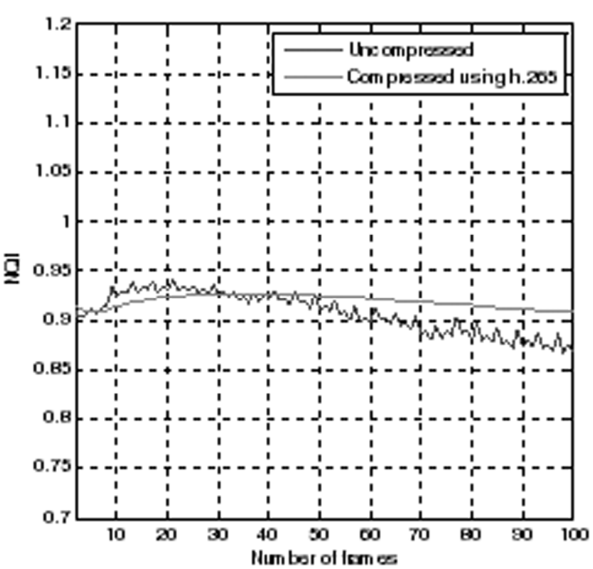
Microsoft visual studio 2010 professional edition for HEVC is encoding and decoding. Elecard StreamEye Studio and CodecVisa for analysis along with MATLAB 2013a for graphical representation. The results show graphs of uncompressed FMRI images and compressed FMRI images by HEVC encoder. Quality evaluation is based on objective analysis parameter may be as follows (but not limited to):



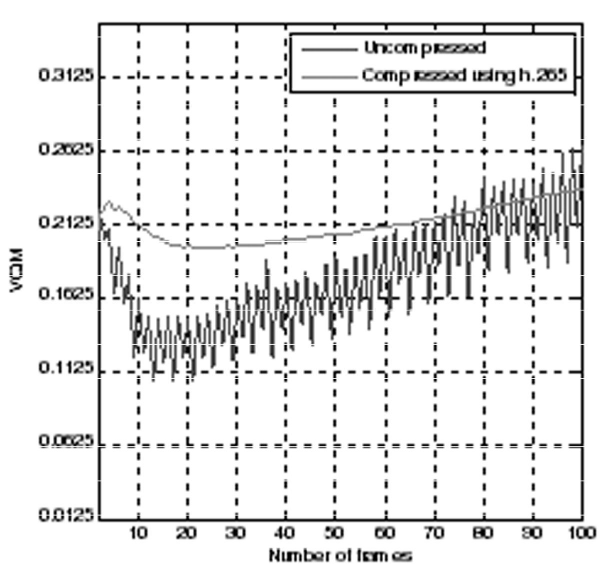
(a) APSNR



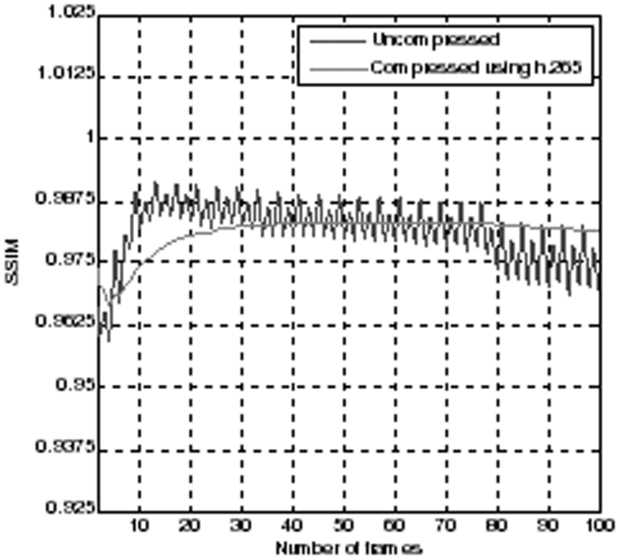
(b) OPSNR



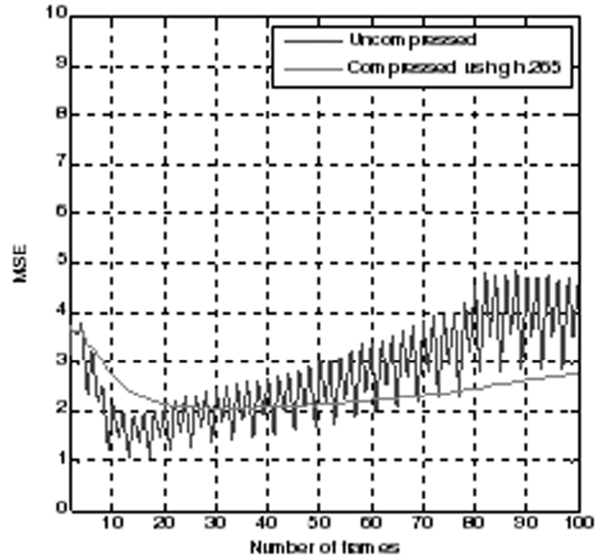
(c) NQI



(d) VQM



(e) SSIM



(f) MSE

Figure 3: (a) APSNR, (b) OPSNR, (c) NQI, (d) VQM, (e) SSIM and (f) MSE of uncompressed, compressed using h.265.

Table 2
Comparison of uncompressed and compressed FMRI using h.264 and h.265

Sr. No.	*Parameter*	*Uncompressed*	*H.265*
1	Compression ratio	1:1	118.23:1
2	APSNR (in dB)	47.163	47.083
3	OPSNR (in dB)	47.163	46.890
4	NQI (in dB)	0.908	0.919
5	VQM (in dB)	0.177	0.213
6	SSIM (in dB)	0.981	0.981
7	MSE (in dB)	2.771	2.415

4. CONCLUSION & FUTURE SCOPE

This paper presents and explore the substantial improvement in compression methods using HEVC (h. 265) encoding technique. This is new and versatile encoding technique in comparison to its predecessors (h. 264). The new encoding technique HEVC providing significant quality and compression for HDTV broadcasting. 4K and 8 K image processing can also utilize the power of HEVC. In progression of these; compression of medical images can offer great deals in telemedicine application. The recent trends of tele-medicine, where the smart mobile like the iPhone is already a great device for doctors and surgeons who can utilize the power of HEVC.

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