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An Efficient Wavelet Based Algorithm for Echocardiogram Video Compression in Medical Application

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Abstract

This paper gives an echocardiogram coding method that takes into visualization modes in order to compress effectively the echocardiogram video. Compression is the process of representing information in a compact form so as to reduce the bit rate for transmission or storage while maintaining acceptable fidelity or data quality.The present problem of video compression is the transmission rate is high and compression ratio is low.so we can't easily found the diaganosis part of the echocardiogram video. Here we are using the proposed method as Adaptive arithmetic algorithm methodology it takes the benefits of particular charecterestics of each visualization mode and to compress efficiently the echocardiogram. After the complete analysis has been designed in order to give a minimum transmission rate for each operation mode, that guarantees efficient and accurate video or image quality. The sufficient transmission rates are 165kb/s for B and color Doppler modes, and 30kb/s for M and pulsed or continues Doppler modes .also the compression ratio is high. These rates are very low compared to the previous results.

Keywords: medical analysis, compression, Adaptive arithmetic coding , echocardiogram, ultrasound, videos.

Introduction

CARDIOVASCULAR disease is the leading cause of death in the modern world. For this reason, it is very useful to have a method and services for an accurate diagnosis and follow-up of patients with cardiopathies. Nowadays, one of the most widely used method is echocardiography. An echocardiogram is depends on the continuous acquisition of ultrasound images of the heart, and it gives several benefits compared with other medical video or imaging techniques. The main advantage is, it is noninvasive, it does not produce ionized radiation, and it is cheap. There are four basic modes of operation recommended by the European Association of Echocardiography (EAE) [1] and the American Society of Echocardiography (ASE) [2] that are incorporated into basic cardiac ultrasound devices. The modes are B, M, color Doppler, and pulsed/continuous Doppler (Fig. 1). The B mode shows the 2-D image that indicating heart and its movement. The M mode shows a 1-D view of the cardiac structures movement over time. Combining, the B and M modes gives us to measure the size, thickness, and movement of the heart. Color Doppler part allows us to analyses the blood-flow velocity through the heart. The pulsed or continuous

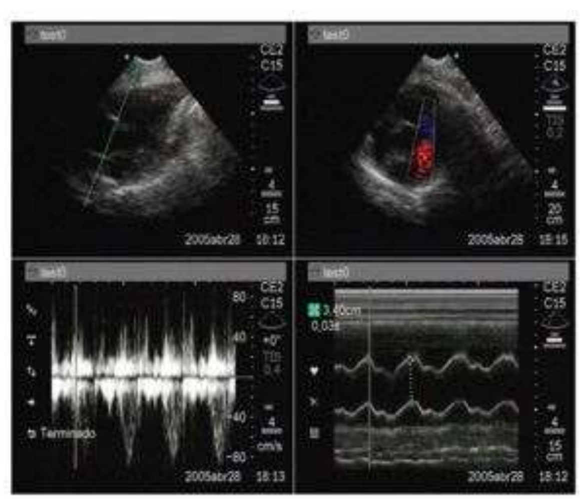

Fig.1. B mode (top left part), color Doppler mode (top right part), M mode bottom right part), and pulsed or continuous mode (bottom left part).

mode gives us to take velocity measurements in a particular segment of the heart. Newly developments in nechocardiography such as color M mode, 3-D echocardiography, and second-generation intravenous contrast agents have widened the usage of the technique. However, many of these recent or latest developments do not necessarily have to be currently included in a routine transthoracic echo studies according to the European Association of Echocardiography recommendations.

In the period of ten years, there has been an increase in the implementation of telemedicine systems and services. The creation of medical video streaming has been made possible. An effective and sufficient compression method is highly important especially for the real-time data transmissions in wireless networks are to they are band limited, time varying, and error-prone. Improving the compression method allows saving cost because low bandwidth is needed and Facilitates that the video arrives at the transmitter without losing the diagnostic information. Other very popular compression methods for medical images and videos are adaptive arithmetic algorithm [7],[8] However, it is very important to point out lose less compression modifies the original video and minimize its quality and it having high compression rate, the high distortion. In medical images or videos, a minimum quality is needed to be able to make an adequate diagnosis. Here the mathematical distortion indices [for e.g. peak signal-to-noise Ratio (PSNR) it can be useful for preliminary and fast measurement of quality, but they are not able to quantify the real clinical distortion. Thus, new indices that include degradation in the diagnosis part of echocardiograms are important. There are several works in which medical opinion has been introduced to assess good clinical quality [11], [12], but these works did not reproduce a standard clinical procedure during an echocardiogram part. This test gives a precise analysis of the realistic degradation in compressed echocardiograms and gives a minimum recommended transmission rate needed for each echocardiographic mode to getting adequate clinical quality. The aim of this paper is three forms.

First, a compression approach for echocardiography based on adaptive arithmetic coding that takes into the specific characteristics of echocardiogram modes is having. Different compression techniques, both for video and image, are used in this techniques depending on the echocardiogram visualization mode in order to compress more accurately the echocardiogram than the techniques present in the literature.

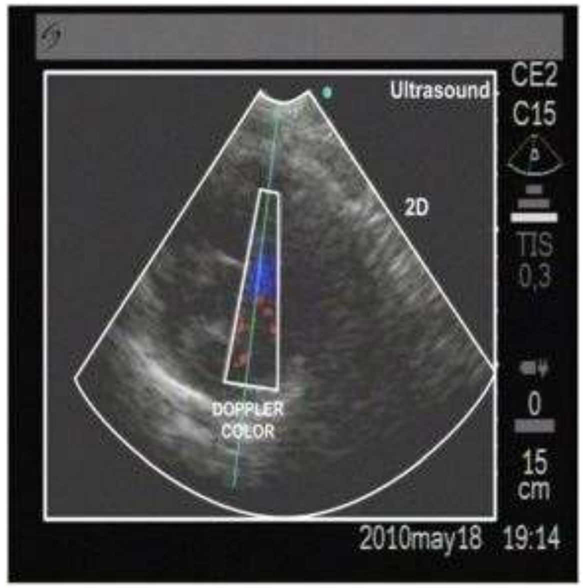

Fig. 2. Section of the ultrasound in the 2-D modes.

Second, an analysis method has been formed in order to perform a clinical analysis for compressed echocardiograms as accurate as the testbeds presented in the previous paper, but low costly in terms of time.

Third, the analysis methodology has been applied in order to provide recommendation of use from a medical point of view for the proposed compression method.

Evaluation Proposal

In this section, the evaluation method is presented. There are two main types of methods to evaluate clinical videos: mathematical and clinical. A mathematical distortion index is easy and fast to calculate, but it is not able to quantify the real clinical distortion. A clinical evaluation is not easy or fast to calculate and the participation of expert cardiologists is necessary, but a precise evaluation of the clinical degradation can be provided. Hence, a clinical evaluation of the compression method is carried out for different rates in order to achieve a precise evaluation of the real degradation in the compressed echocardiogram and to provide a recommendation for echocardiogram compression. In order to evaluate a wide range of transmission rates, but saving time with respect to the previous evaluation method presented in [5] and without losing accuracy.

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Fig. 3. Images of the B mode compressed at different rates with the proposed method.

Three cardiologists, who were not involved in the evaluation, participated in the clinical testbed design. In the first phase, a fast and simple evaluation is made using a semiblind test for different transmission rates in order to select two that are at the limits of acceptable clinical quality for each mode. These two rates will be evaluated in more detail in the second phase using a blind test in order to provide the recommended transmission rates.

A. First Phase: Semiblind Test

The objective of this test is to determinate in a fast and subjective way whether the cardiologist would be able or not to make the same diagnostic with the original and compressed video. This test consists of three different parts; see Fig. 5. The first part permits us to measure the cardiologist's opinion about the similarity between the compressed echocardiogram and the original video. The second part is a question about whether the cardiologist's diagnosis would be the

1.Measure of similarity between the original X mode video and compressed one.

1: very differed	2: differed	3: acceptable	4: similar	5: identical

2.would you give the same diagonosis with both videos for the X mode?

YES	NO

Fig.5. Semiblind test: comparison of compressed echocardiogram with the original video.

same for both videos, the original and the compressed. The third part invites comments, if any. These questions are answered for each echocardiogram mode. In order to have an estimation that directly reflects the distortion in the diagnosis content of every mode in the echocardiogram, a clinical distortion index for the semiblind test (CDISB) is calculated with all the information collected for each mode, cardiologist and transmission rate. This is defined as

$$CDI_{SB}=\frac{1}{2}*\frac{(5-C)}{5}+\frac{1}{2}*(1-D) \quad ---(1)$$

where C is the measurement of similarity between the original and compressed videos (1–5) and D is the answer to the Boolean question about the diagnosis (1 YES, 0 NO) for the mode being evaluated (see Fig. 5). The CDISB is directly related to the clinical distortion of the echocardiogram. The lower the value of CDISB, the lower the distortion in the diagnosis content of the compressed echocardiogram. The CDISB could be grabbed into quality ranges, thus making it possible to classify the echocardiograms. Cardiologists involved in the study considered that it would be more practical to split the CDISB values (0–0.9) into three ranges.

1) The same diagnosis is possible (D = 1) with acceptable quality ($C \geq 3$): CDISB ≤ 0.2.
2) The same diagnosis is possible (D = 1) but with low quality ($C < 3$): $0.2 <$ CDISB ≤ 0.4.
3) The same diagnosis is not possible (D = 0) with low quality ($C < 3$): CDISB > 0.7.

It is important to note that there are no CDISB values between 0.4 and 0.7. It is because the cardiologists decided that the same diagnosis is not possible (D = 0) with acceptable quality ($C \geq 3$). This implies that if the same diagnosis is not possible, the quality has to be unacceptable. The CDISB values are used to discard the transmission rates that are not in the acceptable range (CDISB > 0.4) and to obtain the two transmission rates that are between acceptable or low quality but with the same diagnosis (CDISB ≤ 0.2 and $0.2 \leq$ CDISB ≤ 0.4) for each mode. In order to assess the test, at least three cardiologists should participate and for each mode several videos of different patients and ultrasound devices should be evaluated. Once the CDISB has been calculated for all the patients, the two transmission rates are selected as follows: the upper rate is the first transmission rate with all the CDISB values of the different patients equal to or lower than 0.2 and the lower rate is the immediately inferior. These two rates are the ones selected for a deep evaluation using a more extensive test, the blind test.

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B. Second Phase: Blind Test

This test corresponds to the same blind test proposed in [5] and consists of three different parts, which are much more extensive than those in the semiblind test.We have maintained this test because it is very complete, and now with the advantage that we just have to evaluate the transmission rates selected in the previous test, saving in this way a lot of time in the evaluation process. The objective of this test is to evaluate whether the same diagnostic is possible or not with both videos, the original and compressed videos. In Fig. 6, the three parts of the test for the color Doppler mode are shown. The first part shows the overall score given by cardiologists to the general video quality.

The clinical distortion index for the blind test (CDIB) is defined as

$$CDI_B = max\left\{\frac{Q_{0}-Q_{r}}{2*Q_0}, 0\right\} + \sum_{1}\left(\frac{|sgn(I_{0i}-I_{ri})|}{2*k}\right) \quad ---(2)$$

where *Qo* and *Qr* are the general quality scores (see point 1, Fig. 6) of the original and compressed videos for the mode being evaluated, respectively. For the scores rating, special attention has been paid to the sharpness and definition of the edges of structures, their clear separation from other structures, and the clarity in blood floods. *Ioi* and *Iri* are the interpretation of the *i*th parameter of the original and reconstructed videos, respectively. These interpretations are translated into numeric factors in order to be used in the equation. The rest of the questions are assigned a value larger than 0 (numbers in brackets are in point 2 of the test shown in Fig. 6). *K* is the number of questions that contribute to each echocardiographic mode. *K* is 9 for the B mode, 6 for the M mode, 5 for the color Doppler mode, and 6 for the pulsed/continuous Doppler mode.

1.General quality score for the color Doppler mode.

1:very bad	2: bad	3:tolerable	4:good	5:excellent

2.provided with an interpretation.

Mitral flow system .	Regurgitation I1	No (1)	
		Yes	Light(2)
			Moderate(3)
			Severe(4)
Aortic flow diast.	Regurgitation I2	No (1)	
		Yes	Light(2)
			Moderate(3)
			Severe(4)
Tricus pid flow	Regurgitation I3	No(1)	
		Yes	Light(2)
			Moderate(3)
			Severe(4)
Septal defect	ASD(I4)	NO(1)	
		YES(2)	
	VSD(I5)	NO(1)	
		YES(2)	

Fig. 6. Blind test for the color Doppler mode.

Evaluation Results

In this section, the evaluation of the proposed codec has been carried out in order to recommend a minimum transmission rate for each operation mode that guarantees an adequate clinical quality for the proposed method.

TABLE I
SEMIBLIND TEST: CDI VALUES FOR THE B MODE

Videos/patients	100kb/s	150kb/s	165kb/s	200kb/s	265kb/s	300kb/s	365kb/s
5	0.85±0.07	0.25±0.07	0.20±0.00	0.20±0.00	0.20±0.00	0.20±0.00	0.05±0.07
6	0.90±0.00	0.80±0.00	0.25±0.07	0.15±0.07	0.15±0.07	0.15±0.07	0.10±0.00
5	0.80±0.14	0.75±0.07	0.20±0.00	0.20±0.00	0.20±0.00	0.15±0.07	0.10±0.00
8	0.25±0.07	0.20±0.14	0.20±0.14	0.15±0.07	0.10±0.00	0.15±0.07	0.05±0.07
10	0.35±0.07	0.20±0.00	0.15±0.07	0.10±0.00	0.15±0.07	0.15±0.07	0.05±0.07
7	0.85±0.07	0.25±0.07	0.15±0.07	0.20±0.00	0.15±0.07	0.05±0.07	0.05±0.07

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TABLE II
SEMIBLIND TEST: CDI VALUES FOR THE COLOR DOPPLER MODE

Videos/patients	100kb/s	150kb/s	165kb/s	200kb/s	265kb/s	300kb/s	365kb/s
5	0.25±0.07	0.20±0.14	0.15±0.07	0.15±0.00	0.20±0.00	0.20±0.00	0.05±0.07
6	0.25±0.07	0.15±0.07	0.15±0.07	0.10±0.07	0.15±0.07	0.15±0.07	0.10±0.00
6	0.20±0.00	0.20±0.07	0.20±0.00	0.15±0.00	0.20±0.00	0.15±0.07	0.10±0.00
8	0.25±0.07	0.20±0.14	0.15±0.07	0.15±0.07	0.10±0.00	0.15±0.07	0.05±0.07
8	0.20±0.00	0.20±0.00	0.15±0.07	0.10±0.00	0.15±0.07	0.15±0.07	0.05±0.07
9	0.75±0.07	0.25±0.07	0.05±0.07	0.10±0.00	0.15±0.07	0.05±0.07	0.05±0.07

TABLE III
SEMIBLIND TEST: CDI VALUES FOR THE M MODE

Videos/patients	10kb/s	15kb/s	20kb/s	25kb/s	30kb/s	35kb/s	40kb/s
4	0.90±0.00	0.80±0.14	0.35±0.07	0.15±0.00	0.20±0.00	0.20±0.00	0.05±0.07
4	0.90±0.00	0.85±0.07	0.25±0.07	0.10±0.07	0.15±0.07	0.15±0.07	0.10±0.00
4	0.85±0.07	0.30±0.07	0.25±0.00	0.15±0.00	0.20±0.00	0.15±0.07	0.10±0.00
4	0.30±0.00	0.25±0.14	0.20±0.07	0.15±0.07	0.10±0.00	0.15±0.07	0.05±0.07
5	0.80±0.00	0.20±0.00	0.15±0.07	0.10±0.00	0.15±0.07	0.15±0.07	0.05±0.07
4	0.80±0.00	0.25±0.07	0.25±0.07	0.10±0.00	0.15±0.07	0.05±0.07	0.05±0.07

TABLE IV
BLIND TEST:CDI VALUES FOR THE FOUR MODES

MODE	B-MODE		COLOR DOPPLER		M-MODE		PULSED/CONTINUOUS	
Bit rate(kb/s)	165	200	150	165	30	35	30	35
Patient1	0.15±0.03	0.15±0.03	0.16±0.12	0.13±0.06	0.15±0.06	0.15±0.06	0.19±0.02	0.16±0.85
Patient2	0.15±0.06	0.08±0.03	0.14±0.06	0.11±0.13	0.31±0.25	0.16±0.03	0.25±0.06	0.13±0.16

Recommendation for the Proposed Codec

As explained in Section II, the CDISB values were considered to obtain the two transmission rates that were used in the blind test. The two rates selected were those marked in boxes in Tables I–III. The standard deviations of the CDISB values are very low for all the modes, indicating low inter observer variability. This is because the cardiologists have the same opinion about the cases in which both videos have the same diagnosis and similar opinions in all the cases about the similarity of the videos, but it is not always the same. As we can see in Fig. 3, the higher the transmission rate, the higher the visible quality. Table IV shows the CDI values for the two selected transmission rates for each mode this is because very good results were obtained for both rates and the diagnosis was practically identical to the original in most cases. In general, the standard deviation of the CDI values is lower for the highest transmission rates. The reason is that for the highest rates the image quality is clearly good whereas for the lowest rates it is little less clear and the cardiologists have slightly different opinions. In Table IV, we can see in the CDI values in figure.

The selected transmission rates are the lowest rates with all the CDI values below 0.25. This constraint leads to the recommendations for transmission rates shown in Table V. If we look at the CDISB values of the semiblind test (see Tables I–III) for the recommended transmission rates, we can see that all the values are equal to or lower than 0.2 except for one mode. Hence, for all the modes except for the B mode a recommended transmission rate with only the semiblind test can be given, being the recommended

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transmission rate that with all the CDISB values equal to or lower than 0.2. For the B mode, the blind test is necessary, because this mode contains much information and it is more difficult to evaluate. Fig.3 shows images compressed at the recommend rate for two modes. The images with lower transmission rates than the recommended can present some artifacts, such as a loss of clarity and sharpness in the edges and structures that may cause clinicians to provide an erroneous diagnostic.

Conclusion

This paper has presented an echocardiogram compression method based on display modes. A comprehensive evaluation has been preformed and minimum transmission rates have been recommended for each mode in order to guarantee suitable clinical quality for the transmission and storage of echocardiogram videos using the proposed technique. The recommended transmission rates are as follows: 165 kb/s for the 2-D and the color Dopplmodes, and 30 kb/s for theMand the pulsed/continuous Doppler modes. These are very good results in terms of bandwidth use, especially for the M and pulsed/continuous Doppler modes that have been obtained thanks to the fact that the compression method takes into account the stationary characteristics of the sweep modes and only a thin slice is compressed for every frame. Moreover, these results make possible the transmission of echocardiogram videos over 3G wireless networks and beyond. The table VI gives the comparison results with previous work.

Table v
Recommended transmission rates to obtain good clinical quality

B	Color Doppler	M	Pulsed/continuous
165kb/s	165kb/s	30kb/s	30kb/s

Table vi
Comparison with previous work

sl.no	method	compression ratio	transmission rate(kb/s)
1	Huffman coding	0.789	626
2	H.264	1.023	400
3	Xvid	1.013	384
4	SPIHT	2.40773	200
5	Adaptive arithmetic algorithm	3.106	165

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