A new approach for echocardiogram compression based on display modes

E. Cavero, A. Alesanco and J. García

***Abstract*— In this paper a new technique for echocardiogram compression is proposed. The traditional video compression algorithms used in echocardiography compress the entire video in the same way and the particular characteristics of the operation modes are not considered. In a general way, the operation modes can be divided into two groups, the sweep modes and the 2D modes, which have particular characteristics in the way of displaying the ultrasound. For this reason, the proposed approach takes into account their particular characteristics and different compression techniques are applied to each display mode. For all modes of operation the new technique has been compared with other compression methods like H.264 and XVID, widely used in echocardiography. Lower transmission rates are achieved with the same Peak Signal-to-Noise Ratio (PSNR) supporting the use of the proposed approach.**

I. INTRODUCTION

Nowadays, echocardiograms are widely used to obtain a precise diagnosis of cardiovascular diseases as well as in the follow-up of patients with cardiopathies. An echocardiogram is based on the continuous acquisition of ultrasound images of the heart, and it presents several advantages compared with other medical imaging techniques: it is non-invasive, it does not produce ionized radiation and is cheap. In a standard echocardiographic examination, four modes of operation can be distinguished: B, M, Color Doppler, Pulse Doppler and Continuous Doppler, as can be seen in the Fig 1. The B mode displays the two-dimensional image that represents the heart and its movement. The M mode represents a cross section that allows accurate measurements of the heart chambers. Together, the B and M modes permit us to measure the size, thickness and movement of the heart. Color Doppler studies allow us to evaluate the blood-flow velocity through the heart, the Pulse and Continuous mode permits us to take velocity measurements in a specific portion.

Digital echocardiographic devices produce high data flows that could cause rapid saturation of the storage devices if the echocardiograms were recorded in their original raw format. For teleechocardiography projects where echocardiograms have to be transmitted in real time, this raw data flow cannot be easily handled by standard communication links. Thus, compression must be applied for both reduction of storage requirements and reduction in the transmission rate. Lossless compression rates (up to 4:1) are not enough and do not solve the problem. Therefore, lossy compression has to be used instead since it is able to reduce the data flow considerably. In the last years, lossy compression algorithms proposed by the Moving Picture Experts Group (MPEG) are very extended and used due to their high efficiency. Nowadays, MPEG-4 codec is one of the most used for compressing video sequences. Xvid codec [1] is an open source implementation of the MPEG-4 standard, and H.264/MPEG-4 Part 10 [2] constitute the most common choices for video compression due to their good compression performance both for real time transmission and storage purposes. For example, these codecs have been used in [3] and [4] for Telemedicine applications dealing with ultrasound videos transmission. However, these video compression algorithms compress the entire video in the same way and the particular characteristics of the operation modes are not considered.

In this paper, a novel video compression approach for echocardiography which takes into account the particular characteristics of the echocardiogram modes is presented. Different compression techniques, both for video and image, are used in this new method depending on the echocardiogram display mode.

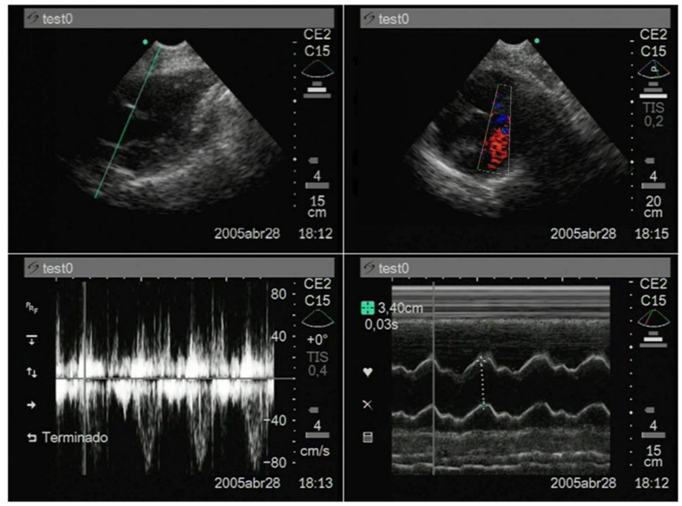

Fig. 1. B Mode (top left), Color Doppler Mode (top right), Pulsed and Continuous Doppler Mode (bottom left) and M Mode (bottom right).

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E. Cavero, A. Alesanco, and J. García are with Communications Technology Group (GTC) in Aragón Institute Engineering Research (I3A), Universidad de Zaragoza (e-mail: `racaj@unizar.es`, `alesanco@unizar.es`, `jogarmo@unizar.es`)

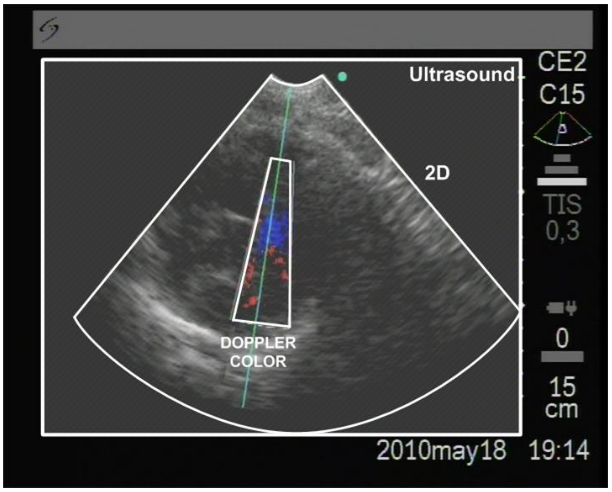

Fig. 2. *Parts of the ultrasound in the 2D modes.*

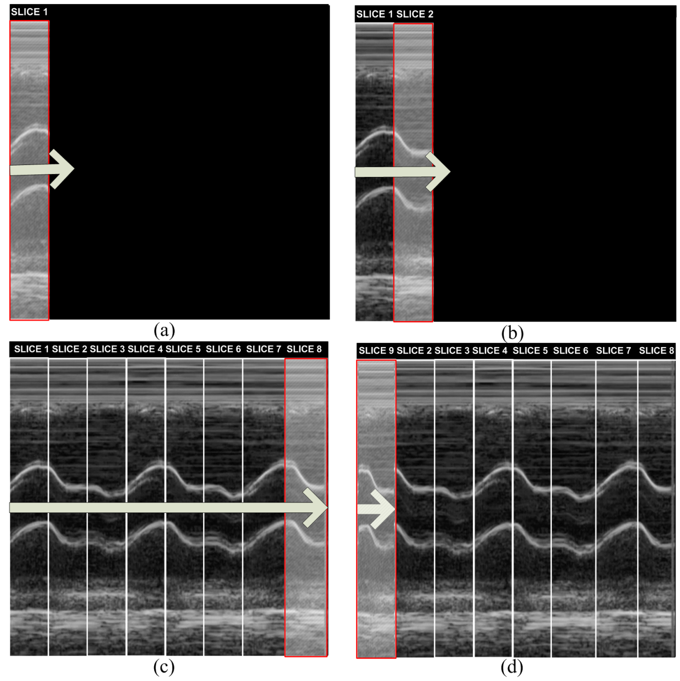

Fig. 3. *Examples of frames in a sweep mode. (a) frame 1, (b) frame 2, (c) frame 8, (d) frame 9.*

II. ECHOCARDIOGRAM COMPRESSION

In this section the characteristics and techniques of compression for each display mode are detailed. In general and according to their visualization similarities, the operation modes can be divided into two groups, the sweep modes and 2D modes.

In a general way, the echocardiogram visualization has two parts, one with the ultrasound scanning and other with some information (such as date, time and mode of operation) around the ultrasound (see Fig. 2). For compression purposes, we have followed the approximation used in many previous works (see for example [5] and [6]) and only the ultrasound part is used.

The echocardiogram frames are coded in YUV format, the most common format to express color in a suitable way for compression, where the luma (Y) has the brightness iinformation and the two chroma (Cb, Cr) components have the color information.

A. Sweep Modes

The sweep modes are M mode, Pulse Doppler mode and Continuous Doppler mode. These modes present the following characteristics. First, the image is displayed gradually, as shown in Fig. 3. A new slice appears in each frame and when all the screen is swept it starts again from the beginning (see Fig. 3 (d)). Eventually, the sweep is stopped by the cardiologist, so the same image is shown in every frame in order to take measurements. Our approach exploits these characteristics, thus only the new slice is compressed for each frame. Besides, these modes do not have any color information, so to code the images only the Y component is used. In order to compress each image slice, two algorithms were selected, Set Partitioning In Hierarchical Trees (SPIHT) [7] and JPEG2000 [8], which are the most common algorithms for image compression due to their good compression performance. They are based on 2D wavelet transform and have multiple resolution, progressive transmi-ssion, lossless and lossy compression. Besides, JPEG2000 has error resilience and SPIHT has been demonstrated to provide good results in the compression of ultrasound images [9]. The slice size depends on the acquiring device and it is an important parameter to be taken into account. Slice height is always large enough for efficiency purposes, but the width can be very small and it affects negatively the compression process. For this reason, a minimum width of 32 pixels is suitable, like it was seen in previous experimental results. Therefore if the slice width is less than 32 pixels, several slices are joined to reach this value and the rest of pixels form the next slice. This introduces a visualization delay in real time applications, but it is always less than 32 pixels (time delay depends on the device).

B. 2D Modes

2D modes are B mode and Doppler Color mode. As can be seen in Fig. 2, these modes can be divided into two parts. The 2D part (see Fig. 2, 2D label) is common for both 2D modes and does not present any color information. The B mode only has this part, so to code it, only the Y component is needed. The Doppler color part (see Fig. 2, Doppler color label) is located in a little region of the ultrasound and has color information, so the color components only change in this region. For this reason, coding algorithms in which the three color planes are linked (like color-embedded 3D SPIHT) are not appropriate for the whole compression and different compression approaches are proposed for the Y component and Cb, Cr components.

1) Grayscale compression: to compress the Y component, 3D SPIHT [10] is proposed. This algorithm presents good results in video compression of medical applications [11]. 3D SPIHT algorithm is an extension of SPIHT from two to three dimensions, two spatial and one temporal. The temporal dimension selected in our approach is 16, so a visualization delay of 16 frames is introduced (time depends on the frame rate). This value is selected because it provides good compression performance (see for example [11]) and does not introduce excessive visualization delay if the codec is used in a real-time transmission environment.

2) Color compression: to compress the Cb and Cr components, Run Length Encoding (RLE) is proposed because of its efficiency on data that contains a high number of sequences in which the same data value occurs in many consecutive elements and as happens in each color component, where all the values are the same except in the color Doppler part (see Fig. 2). Besides, RLE is an algorithm that does not introduce losses in the compression.

III. Results and Discussion

The ultrasound videos used in this study were acquired by an experienced cardiologist in echocardiography using a portable ultrasound device, SonoSite SonoHeart Elite. For this initial study, 60 minutes of echocardiogram which belong to three patients with different pathologies have been acquired. Each operation mode has 12 minutes sufficiently representative. The videos have a frame rate of 25 fps and a resolution of 720x576 pixels all the screen. Each pixel is codified in YUV12 format (12 bits per pixel). The echocardiogram visualization has two parts, one with the ultrasound and other with some information around the ultrasound (see the Fig. 2). As discussed previously, for the compression only the ultrasound part is used, so the resolution for sweep modes is 480x440 pixels and for the 2D modes is 512x416 pixels. In the sweep modes for the ultrasound device used, 64 frames are needed to sweep all the screen. The slice width is less than 32 pixels, so 14 slices of 480x32 are compressed and the last one has been added 480x8 black pixels. The added visualization delay is less than 4 frames (0.14 seconds).

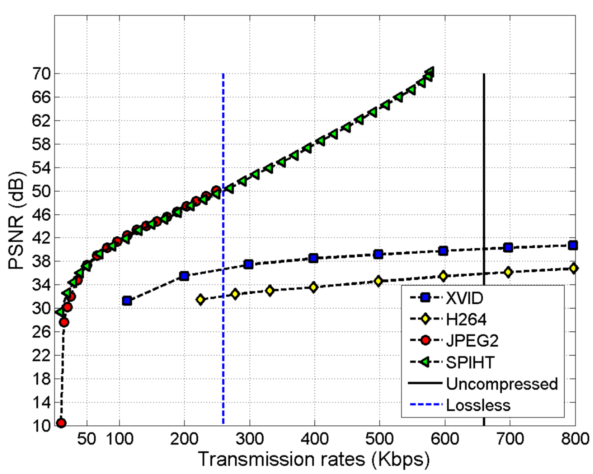

Fig. 4. *Rate-distortion curves for M Mode.*

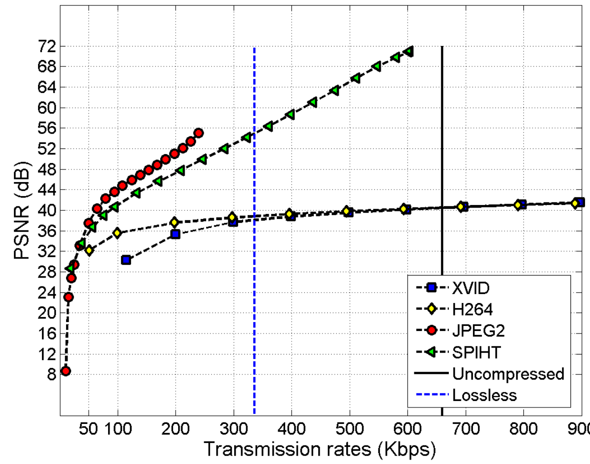

Fig. 5. *Rate-distortion curves for Pulsed Doppler Mode.*

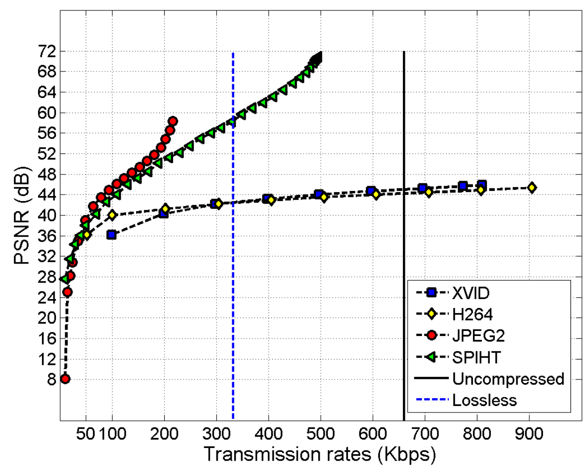

Fig. 6. *Rate-distortion curves for Continuous Doppler Mode.*

In order to evaluate the different compression techniques for each operation mode, the mean Peak Signal-to-Noise Ratio (PSNR) of the three videos is calculated for different transmission rates and the proposed technique for each mode is compared with the traditional video codecs used in ultrasounds applications, Xvid and H264, which compress all operation modes of the same way. Xvid and H264 have been configured with constant bit rate (CBR) and one pass encoding. Fig. 4, Fig. 5 and Fig. 6 show the results obtained for M, Pulsed Doppler and Continuous Doppler modes respectively. In vertical lines the transmission rates without compression and with JPEG2000 lossless compression are represented to compare the lossy with lossless compression techniques. The proposed technique outperforms XVID and H264 for all transmission rates, being this gain more significant for PSNR values higher than 50 Kbps. For sweep modes, two algorithms were tested. SPIHT works better for transmission rates from 10 kbps to 50 kbps and JPEG2000 works better for transmission rates higher than 50 kbps, but

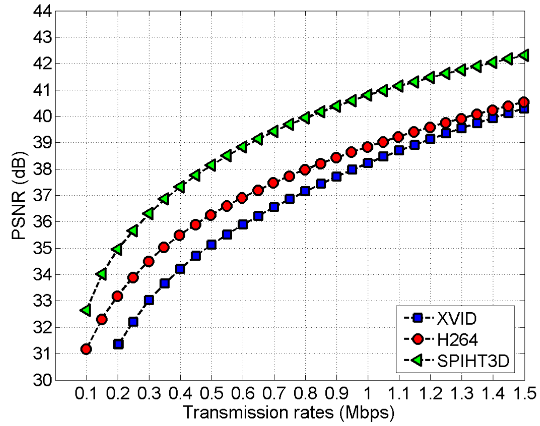

Fig. 7. *Rate-distortion curves for 2D Mode.*

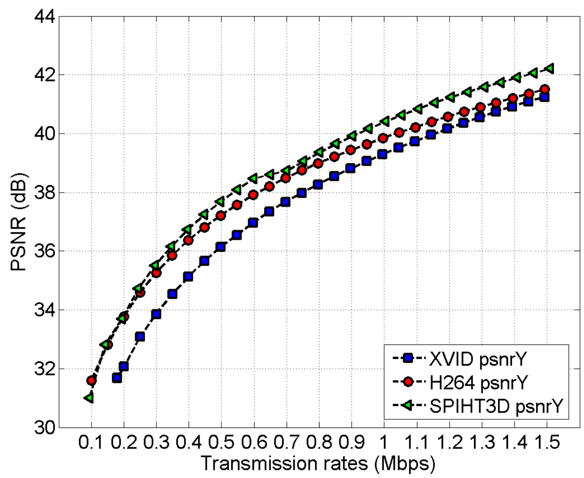

Fig. 8. *Rate-distortion curves for Doppler Mode.*

for the M mode all PSNR values of the SPIHT are higher. It is very interesting to note that for sweep modes (see Fig. 6 to 8) a significantly high PSNR (almost 45 dB, which is practically indistinguishable from lossless compression) is achieved with a very low transmission rate (100 Kbps) using the proposed technique. Fig. 7 shows the PSNR obtained by the Xvid, H264 and the proposed method based on 3D SPIHT for the B mode. A significant improvement is achieved with the proposed method for the B mode and the PSNR values of the proposed technique are always higher than for the other techniques. Fig. 8 shows the PSNR obtained by the proposed method, H264 and Xvid for the component Y of the Doppler Color mode. An improvement is achieved with the proposed method and only for very low transmission rates (less than 100 Kbps) PSNR values of H264 are higher than values of the proposed technique. The rest of the PSNR values are higher for the proposed technique. Results for the color components are not shown, because for the proposed technique (RLE) there is not any loss compression and with Xvid and H264 all PSNR values are higher than 43 dB, so all techniques have an excellent color quality.

IV. CONCLUSIONS

In this paper a new compression technique for echocardiogram is proposed taking into account the particular characteristics of each display mode and using different techniques for each one. In general, there are two display modes, sweep modes and 2D modes. In the first ones only a little slice is compressed for each frame and in the second ones different algorithms are used to compress the grayscale (3D SPIHT) and color (RLE) information. The results obtained with the proposed technique have clearly shown the improvement performance in terms of PSNR as compared to other methods for all operation modes. In this initial study only the results of one ultrasound device and three different videos are shown, but other videos and devices will be evaluated in the next studies and it is expected that similar results will be obtained.

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