

AN APPROACH TO DISTRIBUTED VIDEO CODING USING 3D FACE MODELS¹

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ABSTRACT

Distributed Source Coding (DSC), formulated thirty years ago, is lately witnessing a great research effort. This effort is encouraged by emerging new applications that could greatly benefit from the properties inherent to DSC, like low complexity encoders and embedded error resilience.

Among the challenging topics related to DSC there is the generation of the Side Information, an estimation made by the decoder of the information being decoded.

This paper quickly summarizes the theoretical bases of DSC and then focuses on the essential task of generating the Side Information, by developing the model-based method drafted by the authors on a previous publication. It is shown that the application of model-based Side Information generation techniques on top of current state of the art DSC-based video codecs provides an improvement of 0.5 to 0.75dB over a wide range of bit-rates. Comparisons against H.264 are also provided.

1. INTRODUCTION

Video coding research and standardization have been adopting until now a video coding paradigm where it is the task of the encoder to explore the source statistics, leading to a complexity balance where complex encoders interact with simpler decoders. This paradigm is strongly dominated and determined by applications such as broadcasting, video on demand, and video streaming. Distributed Video Coding (a particularization of Distributed Source Coding) adopts a completely different coding paradigm by giving the decoder the task to exploit the source statistics to achieve efficient compression. This change of paradigm also moves the encoder-decoder complexity balance, theoretically allowing the provision of efficient compression solutions with simple encoders and complex decoders. This coding paradigm is particularly adequate to emerging applications such as wireless video

cameras and wireless low-power surveillance networks, disposable video cameras, medical applications, sensor networks, multi-view image acquisition, networked camcorders, etc., where low complexity encoders are a must because memory, computation, and energy are scarce.

However, even though the theoretical bases for Distributed Source Coding were set thirty years ago with the work by Slepian & Wolf [1] (for the lossless case) and Wyner & Ziv [2] (for the lossy case), it has been only recently that research on the topic has taken a new momentum. This research has been encouraged by the rise of some new applications, and has been led mainly by Ramchandran et al. [3] and Girod et al. [4]. A good review of other works can be found in [4].

Although Distributed Source Coding can be used in other areas, like Robust Channel Transmission, this paper focuses purely on the aspects related to compression using low-complexity encoders.

The novelty presented here is the combination of model-based and block-based side information generation techniques, and the iterative refinement of them both. A predefined 3D model of a human head is used, therefore restricting the area of application of this codec, but also, by focusing on a particular application (like video-conferencing), the decoder has extra knowledge that can be used to help the decoding process. Previous work on these issues was presented in [5] and [6].

This paper is organized as follows. Section 2 presents a quick review of the Slepian and Wolf's and Wyner and Ziv's theorems for Distributed Source Coding. Section 3 then summarizes the approach followed in [4], for the particular case of Distributed Video Coding as it provides the basis of our codec. Next, Section 4 introduces a recent block-based motion-compensated interpolation technique that uses refinement of the motion vectors. Section 5 proceeds to present the model-based approach. Simulation results and comparison to current state-of-the-art are given in Section 6, and, finally, Section 7 draws some conclusions.

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The block-based motion-compensated temporal interpolation (MCTI) is created by using information only from neighboring Intra frames. At the same time, the Parameter Extraction module “fits” a deformable 3D model of a human head [8] to the same neighboring Intra frames. This means that all the parameters that control the deformation of the model, like position, rotation, mouth opening, etc. have to be found. These parameters are then interpolated and passed to the Parameter Application module, which creates a synthetic image to be used as Side Information. The parts of the frame not covered by the 3D model are filled with the MCTI estimation. At this point an initial Side Information has been created and is ready to be used by the Wyner-Ziv decoder.

In the Parameter Application stage, the interpolated parameters only allow the creation of “wireframe” images like the ones in Figure 2, therefore, to give the synthetic images a more realistic look, they have to be textured. For example, the textures can be taken from the neighboring Intra frames and averaged. Taken as a whole, the parameter analysis and synthesis stages perform image warping, in a way similar to mesh-based interpolation, displacing all the pixels inside a reference triangle into the destination triangle. The main advantage of this method over block-based interpolation is that contiguous triangles in the reference frame continue to be contiguous after warping, so no blocking artifacts are created. Figure 2 shows how the pixels inside the reference triangle adapt to the shape of the destination triangle by shrinking or expanding as necessary.

Once an initial Side Information has been created, it is combined with the Wyner-Ziv data in the distributed decoder, and a *Partially Decoded Frame* is produced. DVC schemes not implementing Side Information refinement directly regard this frame as the output frame. However, since this partially decoded frame contains information that was not present in the reference frames used to create the Side Information, it is worth using it to improve the Side Information. It can be used in the MCTI module to refine the motion vectors, as explained in Section 4, leading to a more accurate estimation of the background. The partially decoded frame can also be used to directly estimate the model parameters, instead of interpolating them from neighboring Intra frames. This means fitting the 3D model to the partially decoded frame, which will lead to a more accurate estimation of the face in the foreground.

This process can be clearly iterated, with each iteration giving more accurate estimations for both the background and the foreground of the frame. These more accurate estimations mean more accurate Side Information that will in turn generate better quality output frames.

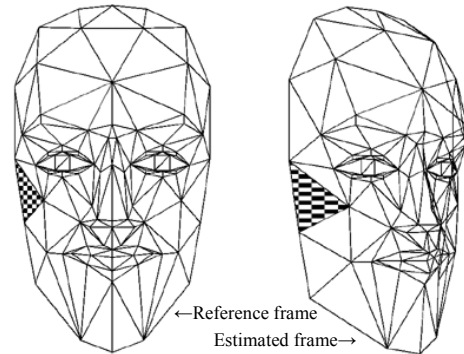


Figure 2 Pixel triangles in the reference frame are warped to build the estimated frame.

6. SIMULATION RESULTS

At the current stage of this research, the model is being adjusted manually. Every frame is fitted to the partially decoded frame and requires user intervention. It is clear that an automatic fitting of the model is needed in real scenarios, but the objective here is to prove the validity of the 3D model-based approach.

The proposed model-based system has been built on top of a DVC codec following the approach in [4]. A return channel is used, and the error probability required to decide if more parity bits are needed is assumed available at the decoder (ideal error detection). The DVC codec used² incorporates a block-based motion refinement mechanism, described in [7] and [9]. 100 frames of the Foreman sequence in QCIF format at 30 Hz. have been coded. Even frames were intra coded and decoded while odd frames, the Wyner-Ziv frames, used the proposed codec. The 3D model used is a slightly modified version of the Candide model [8], using two reference frames for the texturing process.

Rate-distortion plots are shown in Figure 4, along with H.264 in intra mode, for comparison purposes with a codec of similar *encoder* complexity. The rate axis is the rate of the Wyner-Ziv frames, that is, the frames that are not intra coded. It can be seen that there are 0.5 to 0.75dB of improvement when the model-based side information is added on top of the existing codec².

Intermediate steps in the decoding of a particularly difficult frame (number 193) are shown in Figure 3. For this frame, the MCTI gives a very low PSNR for the area of the face, which is partially corrected by the model. It can be seen that the initial Side Information (images **b**) and **f**) has already better quality when using the model-based approach. After two bitplanes have been decoded (images **c**) and **g**) Side Information refinement has fixed most of the errors in the initial estimation. In the final results (images **d**) and **h**) the difference between the two approaches lies only

² This software is called DISCOVER-codec and is the copyrighted work of the research project "Distributed coding for video services" (DISCOVER), FP6-2002-IST-C contract no.: 015314 of the European Commission. It cannot be copied, reproduced nor distributed without the consent of the project consortium.

The DISCOVER software started from the so-called IST-WZ software developed at the Image Group from Instituto Superior Técnico (IST), Lisbon-Portugal (<http://amalia.img.lx.it.pt/>), by Catarina Brites, João Ascenso, and Fernando Pereira.

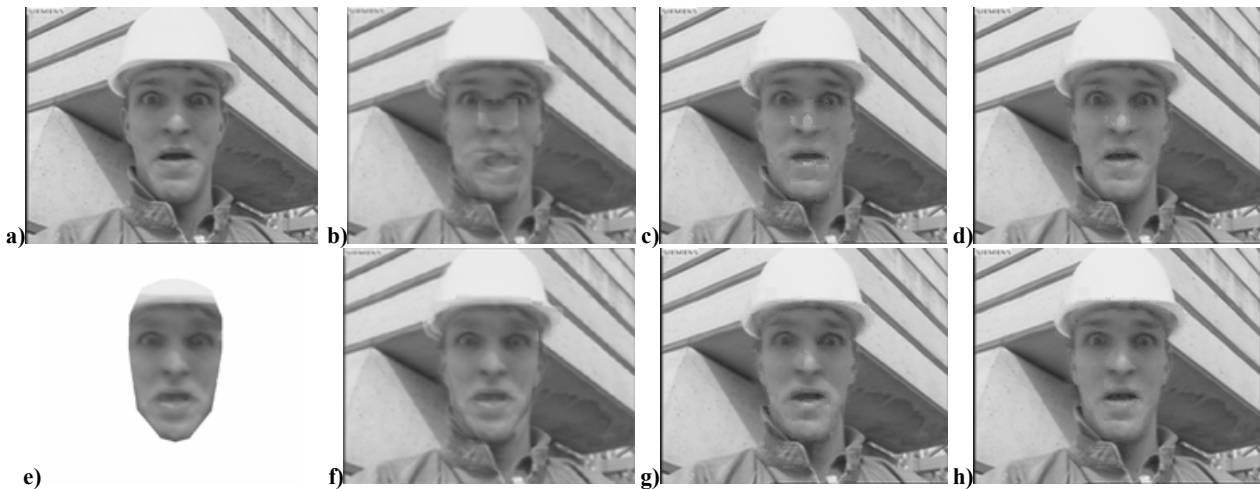


Figure 3 Frame 193 of the QCIF Foreman sequence. **a)** original frame. **e)** image generated by rendering only the 3D face model. **b), c)** and **d)** use the base Wyner-Ziv codec. **f), g)** and **h)** use the proposed Model-based codec. **b)** and **f)** initial Side Information. **c)** and **g)** results after decoding two bitplanes. **d)** and **h)** final results (decoding four bitplanes).

in the last four bitplanes, which have not been transmitted and therefore rely solely on the Side Information.

It is interesting to note that the model does not suffer (and will never suffer) from the triple-eye effect, although it comes with its own artifacts, like the seams at the perimeter of the face. It is also worth mentioning, that the approach is still very far (more than 10dB) from current H.264 interframe coding results, so more work is needed to decrease the current gap of DVC systems and current state of the art of hybrid codecs.

7. CONCLUSION

This paper has shown the importance of generating a good Side Information in order to increase the performance of a Distributed Video Coding scheme. A scheme using model-based Side Information has been proposed which improves the performance of an existing state-of-the-art DVC codec by 0.5 to 0.75dB depending on the bit-rate.

Moreover, the proposed Side Information generation method allows iterative refinement of its parameters (the 3D face model deformation parameters) which can greatly increase its performance.

8. REFERENCES

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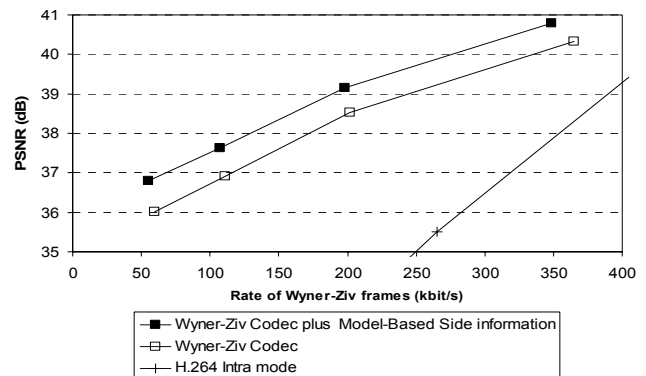


Figure 4 Rate-distortion comparison of the model-based approach with the base Wyner-Ziv codec and H.264 in intra mode. Foreman QCIF @ 30 Hz (rate of the Wyner-Ziv frames 15 Hz)

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