

# Distributed video coding for periodic video sequences

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## ABSTRACT

Distributed Video Coding (DVC) is a very active research field that aims to provide simple encoders, needed by many low resources applications. Unfortunately, all the proposed implementations of this type of coding claim that there is no way to design such a system as described by the distributed Source Coding (DSC) theory. With unconvincing results, such a system can only be combined with conventional coding. In this paper, we will show that there is at least one situation where DVC can be applied directly and efficiently. Thus, we adapt and apply the DVC concept to periodic video sequences (PVS). For these sequences, we will propose a new technique to create the side information (SI), where intra coded frames and motion estimation are no longer needed, which makes this technique very simple and yet very effective. The experimental results show a very good performance, and in some cases, we can even outperform H.264 Inter coding.

## Keywords

DVC, periodic video sequences, Side Information, WZ coding.

## 1. INTRODUCTION

Periodic video sequences (PVS) are a very interesting field to study, because this phenomenon surrounds a lot of imaging and video applications. As interesting applications of PVS, we can list: the artificial satellite motion and panning surveillance cameras, where the scenes are monitored in a periodic way. When this movement is regular, it can be perfectly predictable. This allows both the encoder and decoder to know exactly the correlation between the frames. This situation makes them a good application candidate for the distributed video coding (DVC). This paradigm is based on two major theorems of source coding: Slepian-Wolf (SW) [1], for lossless distributed source coding and Wyner-Ziv (WZ) [2], for lossy coding with side information (SI). DVC is a new coding paradigm that shifts the compression complexity task from the encoder toward the decoder while maintaining the compression efficiency, where it exploits the correlation between the main information and the SI at the decoder, the DVC claims that the result achieved is similar as when the

correlation is exploited at the encoder. In this case the SI is the most important information in the whole DVC paradigm because it plays a crucial role on the overall achieved RD performance. It seems that there are no situations where WZ coding can be applied directly. It can be only combined with classical video coding techniques. As a result, in all the proposed DVC coding models [4], the video sequence is divided into two parts: key frames and WZ frames. The channel codes based DVC techniques exploits the SI at the decoder to correct the main information. In state of the art, all proposed SI generation techniques are based either on interpolation or extrapolation, using Motion Estimation (ME) and Motion Compensation (MC). The intra coded key frames [4], key blocks [5] or a hash [6] are selected as spatial or temporal neighbors of the WZ information, to ensure that a correlation exists (but not completely known) between the two parts, to extract a good SI. This problem doesn't exist for PVS, because when video sequence is divided into a group of periods, we know that all frames located at the same temporal position of each period are extremely correlated. Thus, if we pick just one period to be SI, we will have a very high degree of correlation between SI and the main information. Therefore, the DVC coding concept is well-suited for PVS.

In this paper, we propose to apply WZ coding to the PVS. In this case, WZ coding can be applied directly without dividing the video sequences into group of pictures; also ME and MC can be avoided. It results

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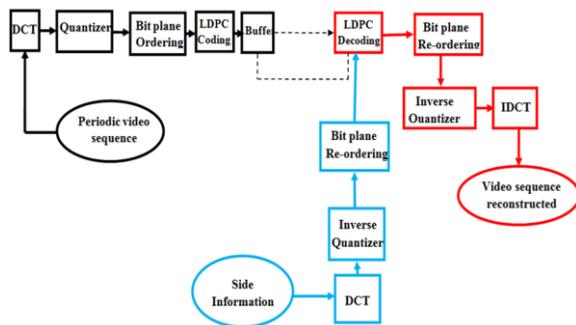


Fig 1. The proposed DVC architecture for PVS

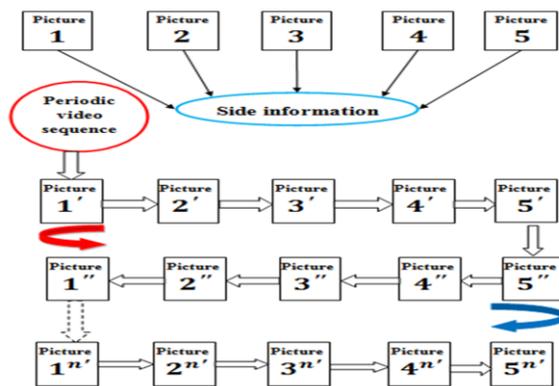


Fig 2. DVC coding for a periodic panning camera

on a very simple technique compared to others. Differently from what is presented in the state of the art on SI generation [3], our proposed technique is based on the following four points, which make its originality and its interest:

- 1- It is possible without use of ME or MC.
- 2- No image classification, i.e. there is no intra images; we work only with WZ images
- 3-The SI can be generated before the starting of coding and decoding procedure.
- 4- SI can be stored directly in the decoder without being coded and decoded with a traditional coding, to maintain the highest quality and degree of correlation. The rest of this paper is organized as follows: section 2 presents a short state of the art on WZ coding. In section 3, we explain how SI is generated in the case of PVS and how the correlation is exploited. In section 4, we discuss the experimental results. Finally conclusion is presented in section 5.

## 2. WINER-ZIV CODING

The Slepian-Wolf and Wyner-Ziv theorems state that the rate achieved by encoding two statistically dependent sources  $X$  and  $Y$ , is almost the same, either when the correlation is exploited by the

encoders or by the decoder only. Practical DVC systems are based on WZ theorem for lossy coding with exploiting the SI. The source  $X$  and the side information  $Y$  are considered to be two independent sources, separated by a virtual dependence channel, where  $Y$  is considered as a “noisy” version of  $X$ . Channel coding is used to correct the errors of  $Y$  to reconstruct  $X$ . The capacity approaching Turbo codes or Low Density Parity Check (LDPC) codes are the most dynamic and efficient codes used nowadays, because they only transmit a minimum number of parity or syndrome bits [7].

In a WZ coding system, the main information to code is  $X$ , while  $Y$  is produced by the decoder based on local information that is supposed to be already highly correlated to  $X$ . Where  $X$  is only a part of the sequence and the other part is Intra coded [4] [5].  $Y$  is generated by motion compensation based on prediction from the already decoded frames. The obtained compression ratio depends on the amount of used channel bits. If  $Y$  is very similar to  $X$ , only a small number of channel coding bits are needed and the bit rate is reduced. This makes creating the best possible SI the most important way to improve the coding efficiency of the WZ coding [3].

## 3. THE PROPOSED DVC SYSTEM

In this section, we describe the proposed DVC system designed specifically for PVS, along with the technique used for SI generation. In these applications, the correlation between the frames is well known by the decoder. For example, if a camera monitors a scene, by turning from left to right and from right to left or around, the result is still a periodic video sequence, composed of a group of periods, where each period is composed of a defined number of frames, as a result frames located at the same temporal position will be extremely correlated. In this case, if a frame is WZ coded, the corresponding frame at the same position at any other period will be highly correlated, and make a good SI candidate. We exploited this idea to design an efficient DVC system for PVS. In order to do this, we picked only one period to be SI, and use it to decode all frames which belongs to the other periods.

Fig.1 illustrates the DVC architecture used in this work. The coding and decoding procedures are exactly the same as in [8] and the only changes are:  
- SI generation and Estimation of the noise correlation parameters

### 3.1 SI generation

Fig.2 explains how the SI is generated and how the video is decoded and reconstructed using this SI. In this example we assume that the video sequence is captured by a panning surveillance camera. Each period is composed of 5 frames. We extract only one period from the whole sequence, store its frames

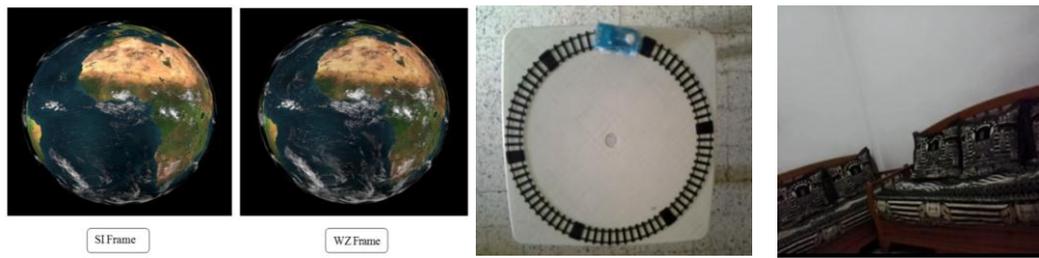


Fig 3. (a) Spinning earth sequence, (b) Train sequence and (c) Video surveillance sequence.

independently at the decoder and consider it as our SI. To ensure the best decoding quality we may also use the last decoded period as SI. To reconstruct the sequence we proceed as follow: Each frame of each period is reconstructed independently, using its corresponding frame in the SI i.e. the frame located at the same temporal position. For example, if we want to reconstruct the frame number 1' of the first period, we perform a correction procedure on the frame number 1 of the SI (frame 1 is located at the same temporal position as frame 1') and so on, for all frames of the being encoded sequence. If the movement of the camera is perfectly or sufficiently synchronized, this technique provides a very high correlation between the SI and the main information, and thus provides a very high quality of SI.

### 3.2 Estimation of the noise correlation parameter:

In DVC, decoding efficiency of WZ frames critically depends on the ability of modeling the statistical dependency between the main information and the SI at the decoder. In state of the art, a Laplacian distribution is used to model the correlation noise, the distribution parameter is estimated online as in [8]. In our system, we use a Laplacian distribution too, but the distribution parameter is estimated offline, because in our case the correlation between all the frames of the different periods is almost the same. This allows us to access them and to choose the best distribution parameter. Here, the distribution parameter is estimated by two different ways:

128	64	32	16	64	32	16	8	64	16	8	8
64	32	16	8	32	16	8	4	16	8	8	4
32	16	8	4	16	8	4	4	8	8	4	4
16	8	4	0	8	4	4	0	8	4	4	0
6				5				4			
32	16	8	4	32	8	4	0	16	8	0	0
16	8	4	0	8	4	0	0	8	0	0	0
8	4	0	0	4	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
3				2				1			

Fig 4. quantization matrices

Test1: we test a number of different values and then we pick the one which gives the best RD performance.

Test2: the distribution parameter is estimated offline between frames of two periods and we use it to decode the frames of another period. For example, in fig.2, we estimate the parameter from frames 1 and 1' and we use it between images 1 and 1''. Each band has its own distribution parameter.

## 4. EXPERIMENTAL RESULTS

Because of the non-availability of standard periodic video sequences, we were forced to design our own periodic sequences. We designed three different test sequences, illustrated in figure 3. In order to evaluate the RD performance of the proposed technique, we compare two different types of DVC with H.264 inter and intra coding: The first is DVC1, where the Laplacian distribution parameter is estimated as in test1 and the second is DVC2, where the distribution parameter is estimated as in test2. To obtain the six RD points we used the six quantization matrices illustrated in figure 4. The first matrix corresponds to the lowest RD point and the sixth matrix corresponds to the highest RD point.

### 4.1 Spinning earth sequence

The Spinning earth is a QCIF synthetic periodic sequence with 30 fps with 350 frames designed with 3DS max, characterized by a slow motion. This sequence represents two spheres: the first is the earth and the second is the moving clouds located above and around the first one, as shown in fig.3a. By adding clouds, we give to this sequence some sort of reality. The pictures contained in SI period and those in any WZ period are slightly different i.e. WZ images are cloudier and darker than the others.

Fig. 5 illustrates the RD performance of our codec for the earth sequence. We can see that the two DVC models outperform the H.264 intra coding for low, medium and high rates. We can also see that DVC1 outperforms DVC2. The RD performance of DVC1 for the same PSNR is better than DVC2 by approximately 50Kbps, for low medium and high rates. DVC1 outperforms DVC2 because its distribution parameter provides better probabilities

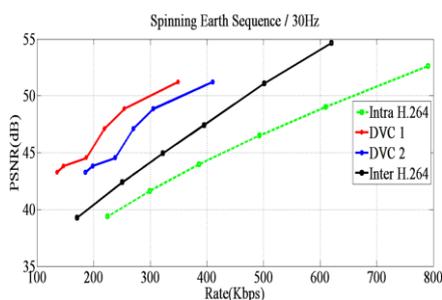


Fig 5. RD performance of Spinning earth sequence.

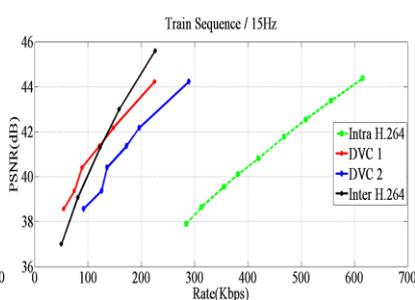


Fig 7. RD performance of Video surveillance sequence.

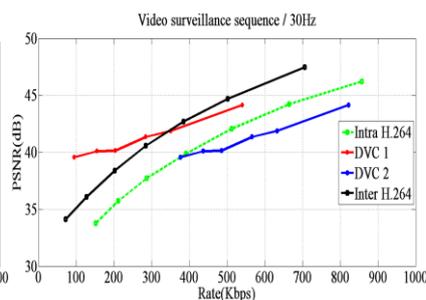


Fig 6. RD performance of Train sequence.

and thus fewer correction bits used. Most important DVC1 outperforms, even, H.264 inter coding due to the high quality of SI. Although, the pictures are not exactly the same due to the clouds movement, but it seems that DVC prediction using the pictures from different periods, is more efficient than the MC of the complex clouds movement using by inter coding.

#### 4.2 Train sequence

The train sequence is a QCIF test periodic sequence with 15 fps with 290 frames, filmed by a camera above the railway and used to follow a moving train, as illustrated in fig 3b.

Fig. 6 illustrates the RD performance of our codec. We can see that the two DVC models outperformers intra H.264 coding for low, medium and high rates. The results show also that the RD performance of DVC1 is better than of DVC2, for the same PSNR, by around 40-80 Kbps. DVC1 outperforms DVC2 because its distribution parameter provides better RD performance.

Here also, DVC1 outperforms H.264 inter coding for low rates. But for higher rates inter is better, because in this test sequence the camera is static and only the train moves. This makes current and precedent images highly correlated, which is easy to code for inter coding.

#### 4.3 Video surveillance sequence

Figure 3c shows this sequence. It is a natural QCIF test periodic sequence with 30 fps with 390 frames, filmed by a surveillance camera. It contains more texture, which makes it more difficult to study. The camera pans from right to left performing a periodic motion. Fig 7 illustrates the RD performance of our codec. We can see that only DVC1 outperforms intra H.264 coding for low, medium and high rates, because the distribution parameter of DVC1 provides better RD performance than DVC2. Fig.7 shows also that DVC1 outperforms H.264 inter coding for low rates, but for higher rates inter is better.

### 5. CONCLUSION

The main contribution of this paper is to target a new

application on DVC field of research, by proposing a new technique of SI generation. It is designed especially for PVS. The major advantages of this technique are the absence of ME or MC, and also no need for intra frames, since we work only with WZ frames.

This makes this technique very simple but it remains very efficient. The results show that our DVC outperforms the H.264 intra coding for all test sequences, and it is even better than H.264 inter coding in some cases.

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