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MJPEG2000 Performances Improvement by Markov Models

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1. Introduction

When the noise dramatically increases, the similarity between successive images is reduced, causing an increase in residue and involving the presence of more indistinguishable, non-zero coefficients. The prediction becomes less accurate and the bitrate rapidly increases. As consequence, more bandwidth is required to transmit a video sequence and pictures quality are affected. To solve this problem, we explored different motion analysis techniques. The analysis of motion is approached mathematically through the extraction of motion information from a sequence of images by means of specific data processing algorithms. Many algorithms of detection, estimation and interpretation of motion were developed with various parameters models. We reworked and developed a Markov model using the potential functions foreseen by the motion detection combining the spatial and the temporal information[1][2]. This algorithm allow a robust moving pixel segmentation and reduces the variation of the luminance that results more often from noise rather than motion. In [3], we explored the impact of adding the Markov technique to MJPEG2000 video codecs. In this work we propose to improve the MMJPEG2000 video codec by adding a new techniques allowing to improve the quality of the decoded sequence. The paper consists of 5 sections devoted to the following topics : First, we provide an explanation of the basis and contribution of the Markov model. Next, we explain the steps followed to embed the Markov algorithm in the MJPEG2000. We evaluate the new techniques and we assess theirs true performance with regard to different video types. We also estimate the different gains in bitrate and the resulting image quality. Next, we explore the possibility to embed the Markov technique on embedded platefroms as Stratix FPGA.

2. Motion detection algorithm based on Markov Model

The purpose of this technique is to localize moving and static areas in a dynamic scene. Then we attribute to each site $s(x, y)$ one of the two labels : 1 if s belongs to a moving area and 0 if s belongs to the static background. The most probable configuration is done by using the Maximum A Posteriori criterion (MAP).

2.1 Notations

Symbols	Explanations
s	Site, imply also pixel with (x,y) coordinates.
$O_{t+1} = \{O_{t+1}(s), s \in E\}$	The absolute value of the frame of difference.
$I_{t+1} = \{I_{t+1}(s), s \in E\}$	The current frame.
$O_{t+1}(s)$	Indicates one site in the O_{t+1}frame.
E	The set of the frame sites.
r,rp,rf	Neighbours (r: spatial, rp and rf : temporal, past and future)
ψ	Modeling the observation.
b	White noise with a variance of σ^2
Um	The energy associated with the model.
Us	Spatial energy.
Ut	Temporal energy.
Vs	Potential function associated with each spatial clique
Vt	Potential function associated with each temporal clique
Vp	Potential function associated with the past temporal clique
Vf	Potential function associated with the future temporal clique

Table 1. Notations

2.2 Algorithm Principle

It is composed of two distinct steps (Fig. 1):

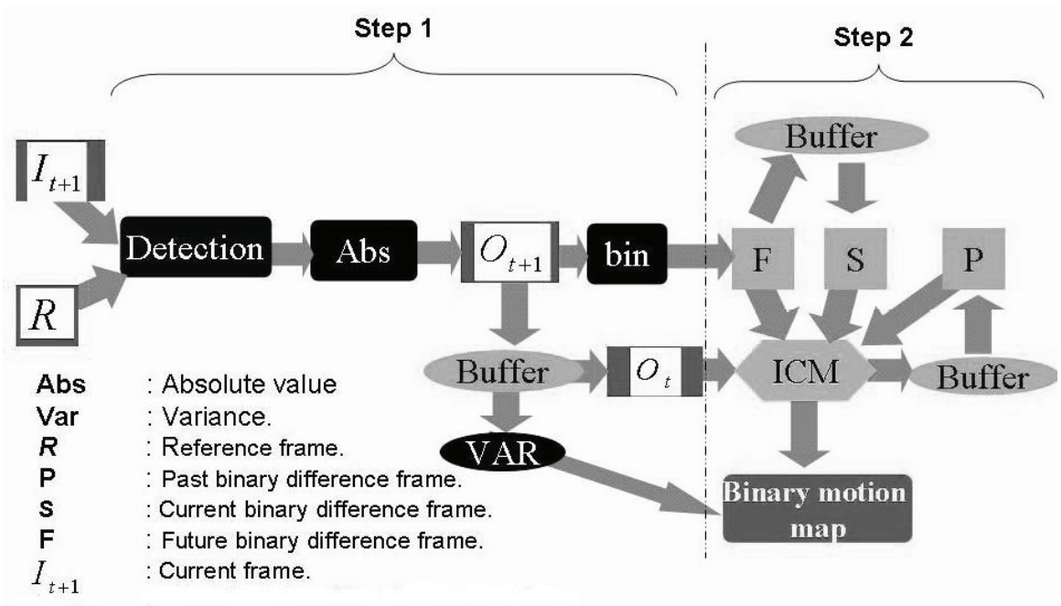


Fig. 1. Generation of the binary map

1. we compute the absolute value of the difference matrix between the current frame I_{t+1} and the reference frame R, we binarize the O_{t+1} matrix by setting a threshold θ, and we

determine the variance of the O_{t+1} matrix.

$$O_{t+1} = |I_{t+1} - R| \qquad (1)$$

2. For each image site, we calculate the local energy relative to both the immobile and the mobile state. After, we allocate the state which minimizes the energy to the site being treated. Leaving the Iterated Conditional Mode algorithm, we achieve an image of minimal energy which represents the binary motion map. The scheme of the complete algorithm is given in Fig. 1. We note that D(t) represents the frame of difference, S the actual binary frame to code and P the past binary frame.

2.3 Energy calculation

The energy expression is the sum of two terms :

- *The energy associated with the data (Ud) (2):*

$$Ud(s) = \frac{1}{2\sigma^2}(O_{t+1}(s) - \psi(s))^2 \begin{cases} \psi(s) = 0, \, if \, s = 0 \\ \psi(s) = \alpha, \, if \, s = 1 \end{cases} \quad (2)$$

$$O_{t+1}(s) = \psi(s) + b \quad (3)$$

- *The energy associated with the model Um (4):* It is a regularisation term. Its expression is given by the some of the spatial energy Us and the temporal energy Ut:

$$Um(s) = Us(s) + Ut(s, rp, rf) \qquad (4)$$

- The energy associated with the model consists of the spatial energy (5) that is supposed to model the consistency and the compactness of a moving object and the temporal energy (6) which represents the variation of the intensity function when the frame changes.

$$Us(s) = \sum_s Vs(s) \begin{cases} Vs(s) = -\beta_s, \, if \; s = r \\ Vs(s) = +\beta_s, \, if \; s \neq r \end{cases} \quad (5)$$

Vs is an elementary potential function associated with each spatial clique. The positive parameter β_s is defined for spatial cliques.

$$Ut(s, rp, rf) = Vp(s, rp) + Vf(s, rf) \quad (6)$$

$\begin{cases} Vp = -\beta_p, \, if \; s = rp \\ Vp = +\beta_p, \, if \; s \neq rp \end{cases}$ $\begin{cases} Vf = -\beta_f, \, if \; s = rf \\ Vf = +\beta_f, \, if \; s \neq rf \end{cases}$

Vp and Vf are two potential functions associated respectively with the past and future temporal cliques. The parameters β_p and β_f are defined for temporal cliques.

2.4 Parameters setting

The different parameters values which were tested and used in previous work are given in Table 2.

The setting of the parameters value is based on empirical observations: good agreement between contours of masks and actual moving objects, contextual homogeneity of detected masks and insensitivity to acquisition noise[6][7].

Parameters	Parameter values
β_p	10
β_s	20
β_f	30
α	15
θ	7

Table 2. Parameters values

2.5 Experimental results

Some of our results can be visualized below (Fig. 2). In the first image, we find simple motion detection by a difference between two consecutives frames. The second represents the binary motion map created from the frame of differences. The multiplication by the mask allows only the conservation of the variation of luminance which reflects the motion.



Fig. 2. Markov tests results

3. Markov algorithm Integration on MJPEG2000 video codec

The JPEG2000 standard is based on two principles: the wavelet transform and EBCOT (Embedded Block Coding With Optimized Truncation). It has better performance in terms of quality/bitrate than the JPEG standard and has more features than other coding standards for still images [8] [9][10]. The compression algorithm considers each component of the image as divided into rectangular tiles treated independently. The first step is the subtraction of an offset coefficient for each tile (DC shift). After that, a lossless color transform RCT (Reversible Color Transform) or ICT (Irreversible Color Transform) is performed. A quantization is achived after selecting the compression mode. The value of this quantization can be modified by using a region of interest (ROI, Region Of Interest). It is a region of the encoded image compressed with higher accuracy at the expense of other areas of the image that are compressed to a lower rate and then degraded [11][12]. The tiles are then broken down into blocks. Coding blocks is done bit-plane by bit plane by an adaptive arithmetic coder (MQ-coder). At the end of the coding, if the output target is not reached, a post-compression algorithm used to truncate the compressed stream. Finally, this flow is encapsulated and organized in one of five modes of data provided by the standard. The video stream MJPEG2000 is a juxtaposition of images compressed by JPEG2000 algorithm. Despite its performance in terms of quality/speed, several authors worked on image stream improving. Two approaches are possible: The first is described in [13] for video monitoring applications.

The image stream is divided into reference image and images containing objects from the regions of interest. The reference images are updated (using a cutting area) by an adaptive Gaussian method [14]. The ROI [15] is obtained dynamically by detecting areas of movement and is encoded by the method "maxshift". It should be noted that in [15], the standard color transform is modified by a logarithmic color transform called LUX, which improves the color rendering of images. A similar approach is presented in [16] where the ROI and the background image are obtained using an algorithm based on Gaussian statistics. We present in [3] a different approach. Indeed, the image stream is separated into reference images and images obtained by masking differences with a bitmap of the movement. This method derives from Frantz Lohier [17] who demonstarted that the masking technique coupled with an encoder MJPEG greatly improves the performance of the encoder. In [18], the technique has been used with an encoder based on wavelets [19], demonstrating the feasibility of extending the technique. Table 3 summarizes the results of the community in this area.

Method	improvement	References
artefacts filtring	PSNR + 0.2 à 0.5 dB	[20]
psycho ponderation	PSNR + 0.2 à 0.5 dB	[21]
motion detecting	bit rate - 10 %	[22]
Post-compression	Speed/memory	[23]

Table 3. state of the art

The methods described in this section are primarily based on the determination of the ROI, the application of the weighting psycho-visual coefficients and the improvement of the wavelet truncation points of the compressed stream. Despite the improvements they make, they remain small compared to the use of methods that alter the flow of images and in particular the differential method (Table 4). We propose in this paper an approach based on the differential method coupled with Markov algorithms to significantly improve MJPEG2000 performances.

Methods	Improvements	Authors
ROI JPEG2000	1 CIF/s GSM. CIF à 660 kbps, PSNR + 4 dB	[25]
differential masking	decreasing the bitrate from 15% to 35%	[18]

Table 4. Quality-bitrate improvement

3.1 Impact of the number of iterations

Respecting the fact that the real-time constraints of digital systems is not compatible with the expectation of convergence of the regularization algorithm, a small number of iterations is used to solve this problem. Its influence on the quality of the images were assessed by measuring the PSNR of the reconstructed images and the entropy of images of differences. Figure 3 shows the impact of the use of 1, 2, 3 and 4 iterations on PSNR. We note that using a single iteration of ICM for the regularization of the binary map degrade the performance of masking. Therefore we chose a single iteration.

3.2 Thresholding

The quality of the final bitmap depends on the result of thresholding. The background noise corresponds to the sites where there is no motion and where the intensity variations is due to the noise of the acquisition system. For further developments, we consider the distributions of

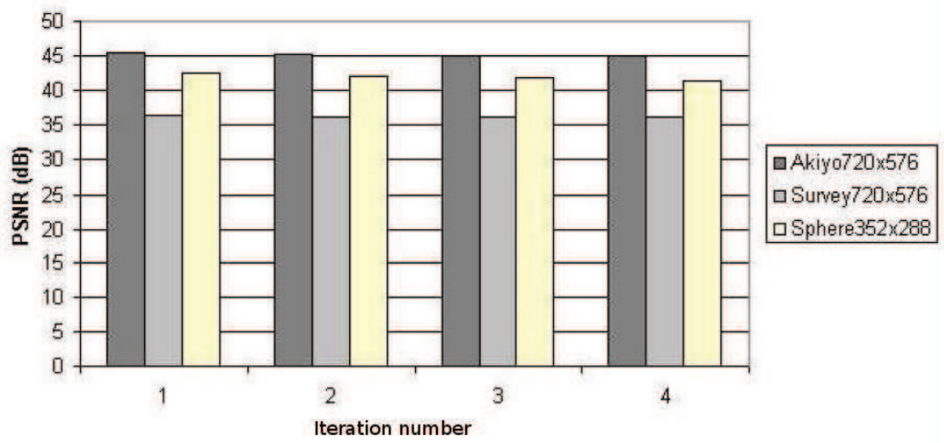


Fig. 3. Iteration impact on PSNR

moving objects and background noise are Gaussian. The analysis of the intensity distribution of pixels in the image is one of the methods allowing the separation of classes. Several methods using histogram thresholding are presented and discussed in [24]. In this section, an adaptive thresholding method based on the histogram of the image observations is proposed. It has low complexity and meet our needs. The conditions of the good working of our algorithm are as follow [25] :

- Fixed camera.
- Illumination changes slowly and gradually.
- The noise is additive Gaussian, uncorrelated, has a low intensity compared to the signal.

Under these assumptions:

- The pixels belonging to moving objects occupy a small portion of the image.

With these assumptions, the difference image contains a large population of pixels close to zero. Figure 4 is an example of image histogram differences of a sequence of video monitoring. An histogram that respects these assumptions can be represented as a bimodal curve. The first lobe is the background (to eliminate). it has a height much greater than the second and a large population of low intensity, close to zero. The second lobe represents the moving objects. Figure 5 illustrates the proposed method.
Based on our method [26] corresponding to a graphical analysis of the histogram to extract the first lobe, we offer an estimation of the mean μ and the standard deviation of background σ_b from the histogram of the image. The first lobe of the histogram is based on the intensity of x expressed as follows:

$$B(x) = \frac{1}{\sigma_b\sqrt{2\pi}} \exp^{-\frac{1}{2}(\frac{x-\mu}{\sigma_b})^2} \tag{1}$$

In the circumstances described above, the average value is the maximum H of the Gaussian and is close to zero. H also corresponds to the maximum of the histogram of the image. If $x = \mu$, we get :

$$B(\mu) = \frac{1}{\sigma_b\sqrt{2\pi}} = max(B(x)) = H \tag{2}$$

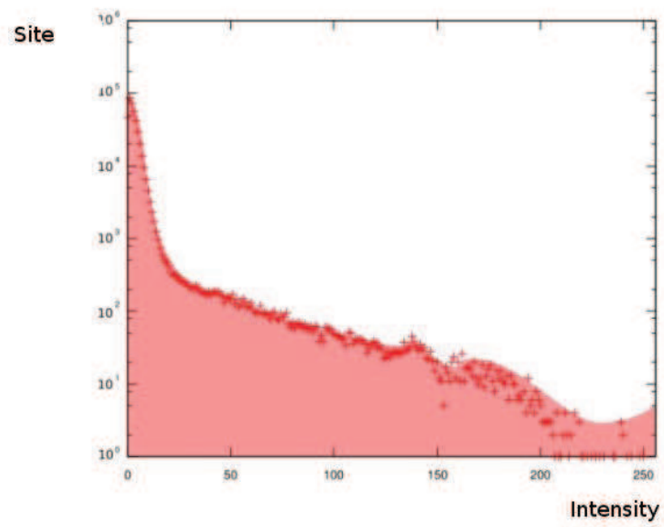


Fig. 4. image histogram

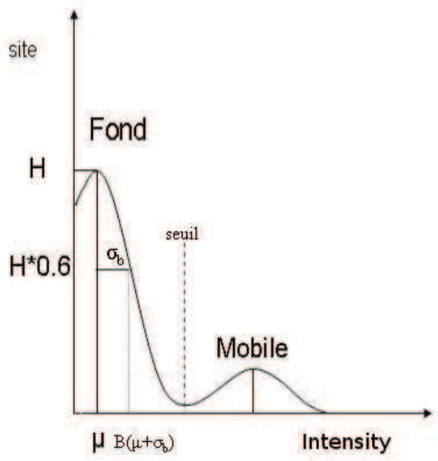


Fig. 5. Gaussian model

we obtain a relationship between the position of the Gaussian and the maximum value H.

$$B(x) = H \cdot \exp^{-\frac{1}{2}(\frac{x-\mu}{\sigma_b})^2} \tag{3}$$

To get an estimate of the standard deviation, we simply compute $x = \mu + \sigma_b$, then:

$$B(\mu + \sigma_b) = H \cdot \exp^{\frac{1}{2}} \simeq H \cdot 0.6 \tag{4}$$

So there is a relationship between standard deviation and the maximum height. If we place ourselves at a height equal to the Gaussian $P(x) = H \times 0.6$, the corresponding value of x gives a direct estimate of $\mu + \sigma_b$. The mean μ and standard deviation σ_b can be obtained by a sequential scan of the histogram. The value of standard deviation is approximated by standing at a height of $H \times 0.5$. Right shifting the bits of the Gaussian height value gives a

good estimate of the standard deviation: $1.1774 * \sigma b$, we define the threshold of binarization as follow :

$$seuil = \mu + k.\sigma_b \tag{5}$$

The parameter k adjusts the rate of the gaussian background elimination. Figure 6 shows the variation of the automatic threshold value according to k.

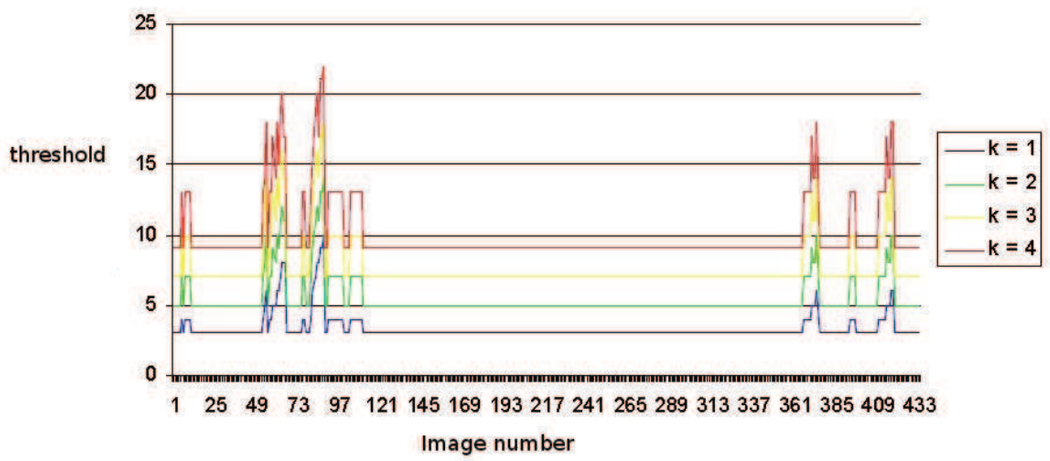


Fig. 6. Thereshold according to k parameter, Akyio séquence

3.3 Reference frames update

In the literature, there are several strategies to update the reference image [27] [28]. Methods related to motion detection zones will update the reference image for each new image if there is a change in the reference image. This approach provides an accurate motion detection but, at the same time, inscreases the number of transmitted reference frames. To refresh the reference image, we used an indexing video technique. The purpuse is to classify the transition effects in a video sequences [29] [30]. Transition effects are abrupt changes of context and gradual changes. We must define two thresholds, τ_1, the high threshold and τ_2 the low threshold, $\tau_1 >> \tau_2$, and compare τ percentage of pixels affected by motion. τ is obtained as follows : P(x,y) is the pixel value of the binary map of moving E(t) at position (x, y), l and c being respectively the number of line and column of the image then:

$$\tau = \frac{\sum_{x=0}^{l-1} \sum_{y=0}^{c-1} P(x,y)}{l \times c} \times 100 \tag{6}$$

In our approach, τ_1 and τ_2 are chosen empirically to values equal to 10% and 40%. We have considered three configurations (Table 5) :

3.4 Masking operation

The masking operation is needed to regulate and eliminate the impulse noise. This operation plays a gatekeeper role and only the intensity variations that are relevant will be retained while others will be forced to zero. The masking operation is obtained by performing a binary AND between the bitmap of motion E (t) and the absolute difference image O (t). At the same

	τ	Motion	Action
1)	$\tau > \tau_1$	high	We send immediatly a reference frame
2)	$\tau_1 > \tau > \tau 2$	intermediate	If 12 successive frame, update the reference frame.
3)	$\tau < \tau_2$	low	There is no need to update the reference image.

Table 5. Reference frames update

time, a dynamic shift is made so that the masked difference image D * t has the same dynamics as the original image. The value $d_t(s)$ of the difference is masked:

$$d_t(s) = 128 + (1 - 2 * sig_t(s) * \left(\frac{e_t(s).o_t(s)}{2}\right)) \quad (7)$$

This forces to zero the pixels which are not detected as motion pixels.

4. Évaluation de l'algorithme

The test database consists of 14 video sequences with very different contexts with a number of images ranging from 100 to 1500. We present two sequences: Akyio and Survey in QCIF format. We performed a software version of the algorithm for masking images of difference. We chose two methods to assess quality:

- The PSNR (Peak Signal to Noise Ratio). It gives a statistical measure of damages.
- Estimation with a perceptual quality metric (double stimulus method) : We compare the original sequence to decompressed sequences. The observer must then assign a rating to the degraded image using a predefined scale. But these tests have the disadvantage of being expensive and time consuming. The perceptual metric represent an alternative to subjective tests. They exploit the HVS characteristics to improve the correlation between the notes that they provide and those given by a set of observers [31]. The perceptual evaluation is performed with the software VQM (Video Quality Metric).

4.1 MJPEG2000 and MMJPEG2000 comparison

The compression system we used to perform our tests consists of three separate modules. The first of these modules is the difference image generator. The used encoder is Kakadu [32]. It follows the standard JPEG2000. We used 4 levels of wavelet decomposition and the "-no_weights" option is enabled. The last module is a module to concatenate the compressed stream and to add the Motion JPEG2000 headers [33]. We notice that we created sequences with reference frames compression ratios equal to 16 and 6 values for difference frames, ranging from 32 to 256.

4.1.1 statistical comparaison

Figure 7 shows the evolution of the PSNR (sequence Survey). It enables a statistical comparison between MMJPEG200 and MJPEG2000. We notice that the MMJPEG2000 video codecs improves the quality compared to a classic MJPEG2000 video codec. The gain varies between 4 dB and 10 dB.

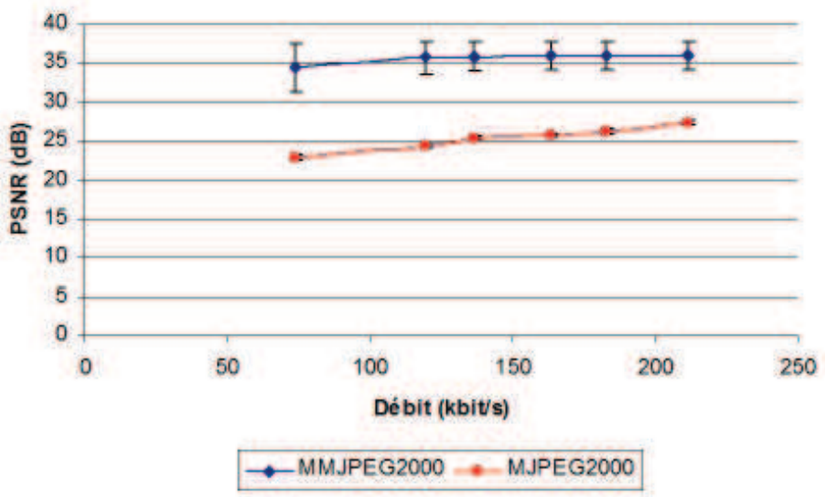


Fig. 7. MMJPEG2000 vs MJPEG2000 : Survey sequence

4.1.2 Comparison with an objective perceptual quality metric

Figure 8 shows the evolution of MOS sequence Survey. It allows a fair comparison between MMJPEG200 MJPEG2000 by estimating the perceived quality. We notice a big improvement except for the low compression ratio.

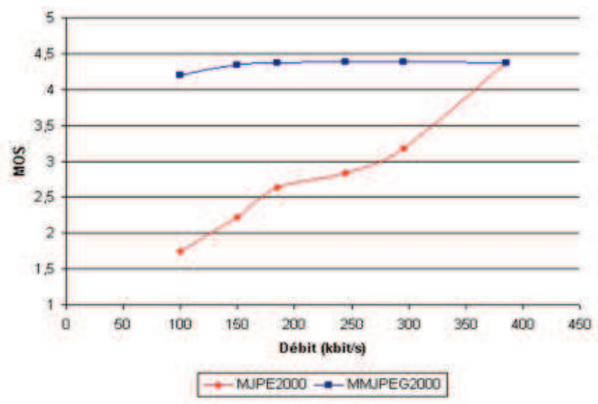


Fig. 8. Perceptual metric quality, Akiyo sequence

4.1.3 Visual comparison

Figure 9 shows part of the sequence Survey. It allows to compare the visual quality of compressed sequence by MJPEG2000, Markov-MJPEG2000 and the original sequence. The sequences are compressed to obtain a rate of 120 kbit/s for the sequence Survey.

5. Implementation on the Stratix FPGA platforme

The design of the Markov motion detection algorithm was done under QuartusII. VHDL language was used for the system description and the synthesis process was oriented for maximum speed. In the conception, we split the algorithm into three functional blocks.

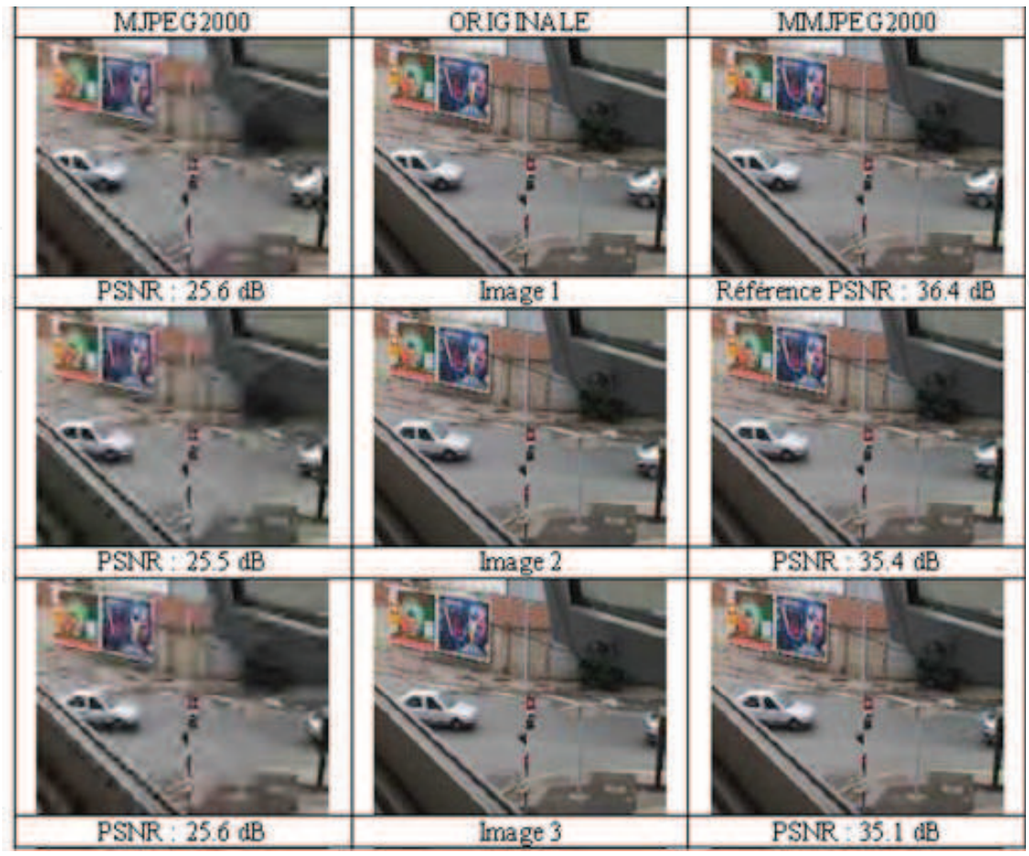


Fig. 9. Comparaison visuelle : séquence survey

The first one is the data controller allowing to grab and store the data to the memory. The next functional block performs the binarization function. The last achieves the energy minimization. In the following, we give more details about the threshold module and the energy minimization module.

5.0.4 *The Threshold module*

The threshold module gives the binary data to the energy minimization module. To perform this task, the differences between matching blocks and the variance must be computed. We note that the difference is obtained by the subtraction between the reference block and the actual block to code. The results are stored in a dedicated memory and the standard deviation calculation is performed at the same time (Figure 10). When the processing is finished, a flag is set indicating to the controller to start the data thresholding. It consists in comparing the pixel differences to a fixed threshold θ.

5.0.5 *The Energy minimization module*

The energy minimization module gets the needed pixel from the thresholding module and decides if the pixel is moving or not. It is composed of four sub-modules (Figure 11).
The line buffer sub-module allow to store the pixel neighbors. In our algorithm, we need 3 lines and the newest line overwrites the oldest one. (L0 is the current line, L-1 the oldest) (Fig

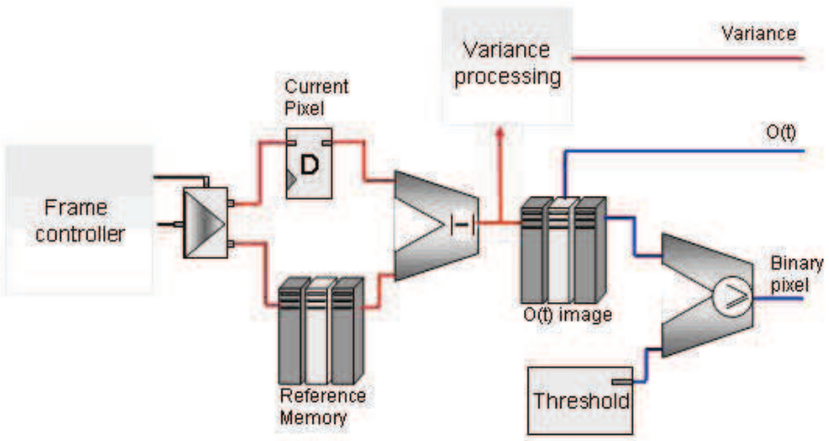


Fig. 10. Threshold module

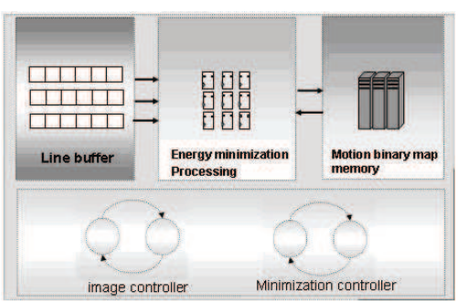


Fig. 11. Energy minimization module

12). We note that the size of the lines depends on the number of columns in the frame. Thus for a bloc size (M x N), we need 3 lines of N columns.

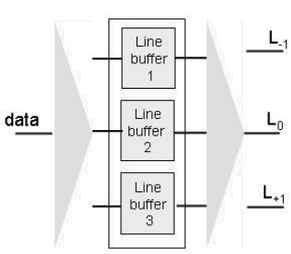


Fig. 12. Line buffer

The minimization is achieved line by line, left to right. We created 9 registers for the spatial neighbors and one register for the temporal. At each clock cycle, the neighborhood is updated with 3 new pixels from the 3 line buffers. Each data moves by one position, so the oldest values are discarded (Fig. 18). To compute the spatio-temporal energy, we compute the energy corresponding to the state of the binary current pixel, the surrounding spatial and temporal pixels. This value is stored in a model energy Look-Up Table. The model energy, the variance and the current observation value are used to process the energy minimization (Fig. 13).

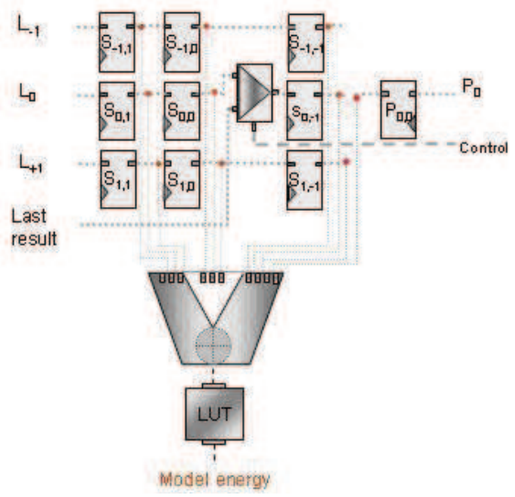


Fig. 13. Model energy processing

5.0.6 Experimental setup and results

The experimental board is composed principally of an Altera Stratix FPGA paltform. We added to the FPGA two daughter boards :

- A video daughter board connected to the digital CMOS camera[34].
- A Lancelot daughter board allowing to display the created mask and the video input[35].

The stratix M-RAM is used to store the binary motion map and the current frame. By this way, both frames can be displayed on a VGA screen (Fig 14).

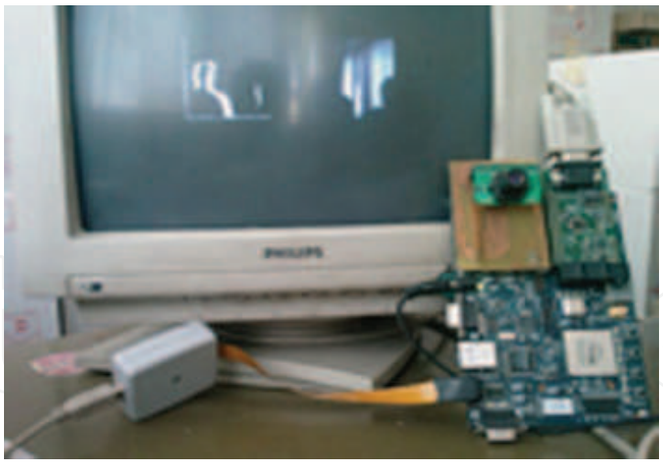


Fig. 14. Motion detection experimental prototype

The system process 3200 macroblock per second (312 us/Macroblock). The maximum IC frequency is 75 MHz. The motion detection IC takes only 4.6% of the total FPGA logic elements. This result allows us to implement more functionality in the FPGA such as the other parts of the H264 or MJPEG2000 video codecs. We used 13 embedded multipliers in our design. The majority are used to compute the variance. Without the embedded Stratix multipliers, we note that the number of used Logic Elements grows by a factor of three and the maximum working frequency fall down to 50 MHZ.

6. Conclusion

Within this framework, we have been interested in the discovery of new methodologies allowing the reduction of the bitrate for noisy sequences while maintaining adequate quality of the rebuilt sequences. Particularly, we have demonstrated that the addition of the Markov algorithm presents an effective solution in reducing the noise contained in the video sequences. We showed that the new Markov/MJPEG2000 video codec improve significantly the performances achived by a classic MJPEG2000 video codec while keeping a standard bitstream. We have also been interested in evaluating Markovian technique under a PC platform and on embedded architectures intended for the multi-media applications. The complete implementation of the Markov algorithm carried out exclusively on a stratix FPGA, demonstrated the possibility of using this technique on embedded architecture.

7. References

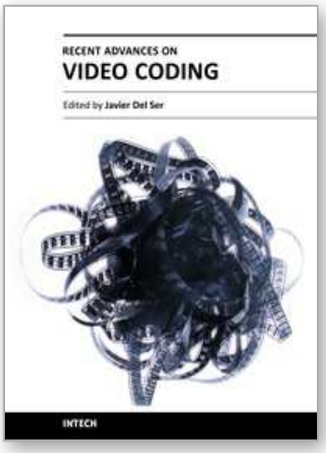
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This book is intended to attract the attention of practitioners and researchers from industry and academia interested in challenging paradigms of multimedia video coding, with an emphasis on recent technical developments, cross-disciplinary tools and implementations. Given its instructional purpose, the book also overviews recently published video coding standards such as H.264/AVC and SVC from a simulational standpoint. Novel rate control schemes and cross-disciplinary tools for the optimization of diverse aspects related to video coding are also addressed in detail, along with implementation architectures specially tailored for video processing and encoding. The book concludes by exposing new advances in semantic video coding. In summary: this book serves as a technically sounding start point for early-stage researchers and developers willing to join leading-edge research on video coding, processing and multimedia transmission.

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