A Hybrid Algorithm using Metaheuristics Applied to H.264/AVC Video Encoder

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Abstract: This paper focuses on the study and the analysis of the dynamic relationship among six parameters of the H.264/AVC video encoder, that are: frame rate, bit rate, quantization parameter for I slice, B slice, and P slice, and the number of B slices in the GOP (Group of Pictures). For this study, it was developed and implemented a hybrid algorithm called Simulator of Metaheuristics applied to a CODEC (SMC). The SMC algorithm consists of two metaheuristics that are Tabu Search and Genetic Algorithm. It tries to find the best configuration of the studied parameters in order to obtain a good quality and compression of the encoded video in the H.264/AVC standard. The SMC algorithm uses a maximization objective function as an objective evaluation method to reach the proposed goals.

1 INTRODUCTION

Algorithms for compression and decompression video, called video CODECs, have been continually improved over the last decade to meet the demands of the market (Golston and Rao, 2006). One of the latest CODECs is the H.264/MPEG-4 AVC (ITU-T, 2007) which was defined as a standard for encoding video for the Brazilian Digital Television System (BDTS), (ABNT NBR 15601:2008; ABNT NBR 15602-1:2008). This standard allows that several parameters can be configured allowing a high flexibility to obtain a good video quality and therefore influencing its performance.

This work focuses on the development of an hybrid algorithm (Glover et al., 1999) called Simulator of Metaheuristics applied to a CODEC (SMC) to define the configuration parameters of the H.264 video CODECs for the BDTS and thus optimize its performance. The solution proposed consists in two metaheuristics, Tabu Search (Glover, 1986) and Genetic Algorithm (Holland, 1975).

The H.264 CODEC configuration problem is treated as a combinatorial optimization problem known as the Selection Problem of Parties (Gonçalves and Resende, 2004) and classified as NP-Hard (Papadimitriou, 1994).

This paper is organized as follow: Section 2 presents the related works. Section 3 presents the proposed solution for the Simulator of Metaheuristics applied to a CODEC (SMC). The Section 4 presents the experiments and results, and the section 5 presents the conclusions about this work.

2 RELATED WORK

A number of authors have proposed algorithms to optimize the performance of the H.264 CODEC (Yasakethu et al., 2008; Cermak et al., 2011; Huang et al., 2006; Nemethova et al., 2004). For evaluating the performance of these algorithms, methods and techniques have been developed to evaluate the perceived quality level of the video content (Sikora, 2005; Moriyoshi et al., 2000; Malvar et al., 2003; ITU-R, 2002). These methods can be mainly categorized into two major classes: the subjective and objective methods (Ries et al., 2007; Seshadrinathan et al., 2009; (Pinson and Wolf, 2003; Wolf and Pinson, 2007).

The objective methods are, in the most of cases, based on an sensitivity framework of the error, being one of the metrics most widely used, the Peak Signal to Noise Ratio - PSNR (Winkler and Mohandas, 2008). In this context, this paper presents an objective evaluation method, based on an objective function proposed by a Simulator of Metaheuristics applied to a CODEC (SMC).

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3 PROPOSED SOLUTION

The SMC computational model in the figure 1 is basically composed of three modules: initial solution, tabu search, genetic algorithm and functional blocks of H.264/AVC.

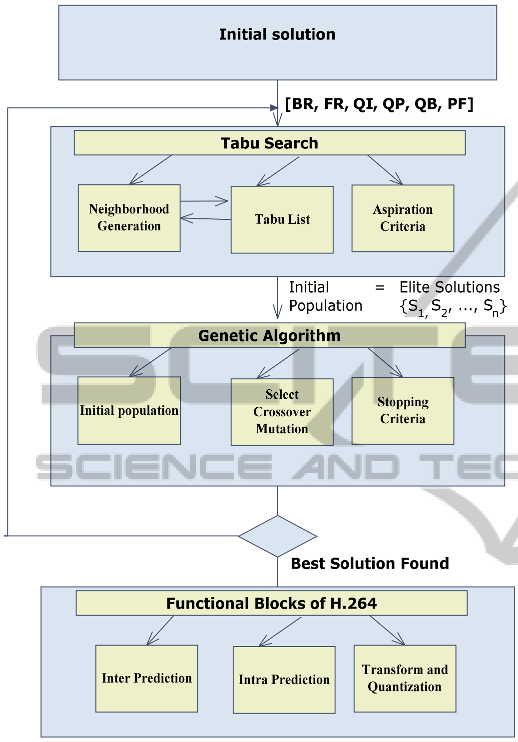

Figure 1: SMC – Computational Model of the Simulator of Metaheuristics applied to a CODEC (SMC).

In the model shown in Figure 1 is provided a viable initial solution to the TS, which consists in a set of six parameters of the H.264. They were obtained by the JIGA of tests from the DigConv project (UNISINOS, 2008) and reached an acceptable PSNR.

The TS explores the search space around this initial solution using six types of neighborhood in order to find a better solution and it uses the equation (1) as the Objective Function. The neighborhood structure consists in 6 movements and the tabu list stores the last 7 tabu movements. The stop criterion applied is the maximum number of iteration without improvement of the Objective Function value (nbmax) and its size was defined in 100. A list of the twenty best solutions found is stored in an elite candidate list. The Genetic Algorithm uses as its initial population the elite candidate list generated from TS which consist in twenty individuals or elite candidates. The chromosome is represented by the six studied parameters. The fitness function is represented by Equation (1). The selection strategy used is tournament selection; the reproduction strategy consists in crossover and mutation with probability equal of 0.8 and 0.2 respectively. The number of generations is 100 and it is used as the stop criteria. If the solution found by the Genetic Algorithm module is better than the solution found by the Tabu Search module then the SMC returns to the Tabu Search module in order to optimize this solution. Otherwise, the SMC is finished.

3.1 Objective Function

The SMC algorithm uses the Objective Function (OF) which is estimated with six parameters (decision variables) as shown by equation (1) and it is a function of maximizing.

$$\text{Max OF} = \alpha_1 BR + \alpha_2 FR + \alpha_3 \frac{1}{QI} + \alpha_4 \frac{1}{QP} + \alpha_5 \frac{1}{QB} + \alpha_6 \frac{1}{PF} \tag{1}$$

The coefficients $\alpha_1 = 7, \alpha_2 = 1, \alpha_3 = 32, \alpha_4 = 24, \alpha_5 = 21, \alpha_6 = 122$, were estimated by calculating the not tendentious weights, the parameters QI, QP and QB are the quantization parameters for I slices, P slices and B slices respectively. The BR value is the bitrate out of the video, the PF value is the number of B coded frames inserted between P slices that is used to determine the initial picture ordering entrance for the video to be encoded. FR value is the framerate for the entrance of the video.

4 EXPERIMENTS

Experimental simulations were performed on the first frames of well-known QCIF (176x144) video sequences. The set of parameters adopted as initial solution by the SMC algorithm is BR=64bps, FR=30.3fps, QI=16, QP=16, QB=18, PF=1. The ranges of values for each parameter are: 0.1 to 192.0 for BR; 0.1 to 100.0 for FR; 0.1 to 51.0 for QI, QP and QB; 1 to 5 for PF.

Two experiments were performed using the SMC algorithm, in order to analyze the behavior of the studied parameters and to verify if they are in agreement with the dynamic H.264 parameters studied in the literature.

In the first experiment 20 units were added to the non-biased weight of BR parameter. The weights of the other variables were maintained with their original non-biased weights. The SMC algorithm was performed 300 times, where in each thirty times it was calculated the average value of each parameter (Table 1).

The experiment continued repeatedly, by adding 20 units to the BR parameter weight until the 200 units. The SMC algorithm was performed 300 times for each change of weight value. All this process was done for all studied parameters. The goal of this experiment is to evaluate the behavior of the mean values of the parameters when one of them has a gradual increase in your non-biased weight and the others parameters remain with their original non-biased weights. These values are observed through the values assumed by the parameters of the objective function.

In the second experiment, the non-biased weight of BR parameter was set aside by assigning zero to it and the other variables remained with their non-biased original weights. The SMC algorithm was performed 300 times, where in each 30 times was calculated the average value of each parameter (Table 3) and was observed how the other parameters behaved without the influence of BR parameter in the objective function. This same process was performed for the all studied parameters and the results are shown in the section 4.1.

4.1 Results of the First Experiment

In the graph 1 (Figure 2) is shown the behavior curves among QI, QP, QB and PF parameters when the non-biased weight of the BR parameter is intensified in the objective function.

In the graph 2 (Figure 2) is shown the curves of behavior between the Objective Function (OF) and BR. In the graph 3 (Figure 2) is shown the curves of behavior between FR and BR.

In the Table 1 is shown the mean values of the parameters and the objective function found by the SMC algorithm in the first experiment.

In the Table 1, each line corresponds to a set of mean values found by the SMC algorithm after it runs 30 times. This set of mean values was used to construct the graphs in the Figure 2. The values highlighted in the table 1 correspond to the minimum and the maximum values found by the SMC for each parameter and the Objective Function.

The graph 1 (Figure 2) is also shown that QP and QB tend to be inversely related and PF has a direct influence on QB. In sum, the more B frames (PF parameter) we have, the more compression a video will suffer (by increasing parameter QB).Thus

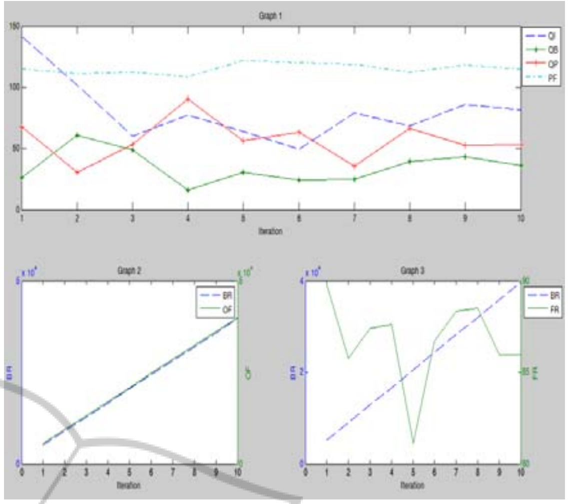

Figure 2: Graphs 1, 2 and 3 of Experiment 1 using the intensification of BR parameter.

Table 1: Mean values of the experiment 1 using BR parameter intensification.

Iteration	AV OF	AV BR	AV FR	AV QI	AV QP	AV QB	AV PF
1	5580.45	5139.68	89.81	141.51	67.86	26.36	115.22
2	9378.80	8988.41	85.76	101.93	30.41	60.87	111.43
3	13195.66	12833.40	87.41	60.09	53.45	48.80	112.51
4	17031.71	16651.97	87.61	76.91	90.46	16.32	108.44
5	20866.86	20512.54	81.14	63.86	56.50	30.82	122.00
6	24695.78	24351.64	86.70	49.59	63.49	24.39	119.97
7	28539.86	28193.17	88.32	79.10	35.43	24.89	118.95
8	32411.56	32036.43	88.50	68.14	66.48	39.50	112.51
9	36240.54	35854.89	85.97	86.01	52.71	43.02	117.93
10	40081.34	39709.56	85.96	81.31	53.10	36.53	114.88

decreasing the video quality can be observed that the algorithm proposed in this paper tries to compensate this loss of video quality by decreasing the quantization parameter of P frames (QP). The P frames serve as a reference to B frames, and thus the algorithm tries to obtain a better image quality.

According to the literature (Yasakethu et al., 2008), quantization parameters, which in this case are represented by QP, QB and QI, influence the amount of spatial detail of the video to be saved.

In Table 1 is observed that the higher values of QP, QB and QI not reach high values in comparison with the values in Table 3 of the experiment 2. This occurs because in the Graph 2 (Figure 2) it is shown a constantly growing of BR parameter. The BR parameter tends to decrease the maximum values of QP, QB and QI parameters, since quantization parameters are inversely proportional to BR when it comes to achieve an improvement image quality. According to the literature (Yasakethu et al., 2008; Kim et al., 2006), quantization parameters influence the bitrate (BR parameter), which means that when the bitrate is increased, consequently decreases the compression of video (lower values of QP, QB and QI) and vice versa, in order to achieve a better quality image.

In the Graph 2 (Figure 2) shows that as the bitrate increases the objective function also increases, which means that the image quality is better. However, according to the literature (Koumaras et al., 2005) improvements of the video quality is not significant for bitrates higher than a specific threshold.

The graph 3 (Figure 2) shows that as the BR grows, the FR fluctuates and it tends to stabilize. According to the literature (Ries et al., 2007), the framerate (FR) may increase or decrease in relation to the increasing of bitrate (BR) due to the type of video content. Ries et al (2005) states that panoramic videos receive a better rating in video quality when the framerate drops. However, dynamic videos receive a better rating when the framerate and bitrate grow together.

It was found that PF and FR parameters obtained a low standard deviation in the SMC. This fact means that the SMC algorithm explored a restricted search space, while the others parameters reached a high deviation standard that means a larger search space was explored. The objective function reached a high deviation standard due to the high deviation standard from the most of parameters.

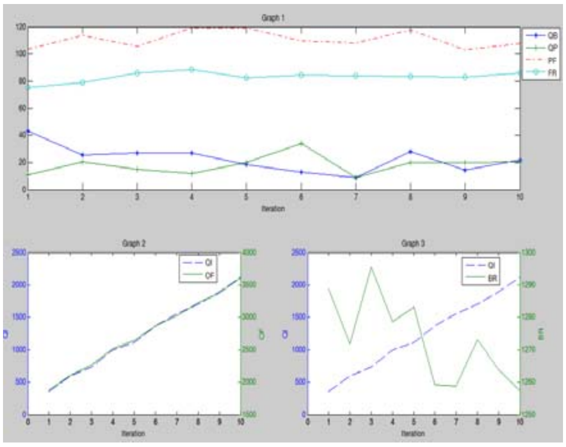

Figure 3: Graphs 1, 2 and 3 of Experiment 1 using QI parameter.

In Figure 3 is shown the graphs of experiment 1 where the non-biased weight of QI is increased in the objective function.

The Graph 1 (Figure 3) shows the curves of behavior of the QB, QP, PF and FR parameters in relation to QI parameter.

In Graph 2 (Figure 3) the QI parameter contributed to increase the objective function (OF). The objective function (OF) reached lower values in comparison with the OF values of the Table 1. It means that the increasing compression of I frames (higher QI) causes a lower bitrate (BR) and it contributes for a lower image quality and consequently a lower objective function value (OF).

Table 2: Mean values of the experiment 1 using the intensification of QI parameter.

Iteration	AV OF	AV BR	AV FR	AV QI	AV QP	AV QB	AV PF
1	1870.69	1288.61	75.21	349.51	10.66	43.00	103.70
2	2110.84	1271.90	78.91	600.32	20.43	25.42	113.87
3	2263.23	1295.40	85.79	734.69	14.87	26.75	105.73
4	2521.15	1278.61	88.39	995.86	11.91	27.09	119.29
5	2641.06	1283.29	82.20	1117.85	19.79	18.65	119.29
6	2865.54	1259.19	84.34	1365.77	34.08	12.69	109.46
7	3023.17	1258.66	83.96	1554.73	8.76	8.96	108.11
8	3227.92	1273.08	83.49	1705.31	20.00	28.12	117.93
9	3373.59	1263.71	82.93	1889.66	19.73	14.53	103.02
10	3620.18	1257.25	85.85	2127.10	20.51	21.70	107.77

In Graph 3 (Figure 3) is shown the relationship between BR and QI parameters. Note that in the first five iterations BR parameter tends to oscillate in a range of its higher values while the QI parameter is growing in the range of its lower values, but as QI tends to grow, BR tends to oscillate in a range of its lower values. In sum, as the compression of I frames increases (QI), the SMC algorithm tries to decrease the bitrate (BR) in order to improve the quality of the image.

The improvement of the image quality can be seen in the Graph 3 (Figure 3) where is shown the relationship between QI and OF. As higher the objective function (OF) is, the higher the image quality is, according to the SMC algorithm.

In Table 2 is shown the results of the experiment 1 where the non-biased weight of QI was intensified in the objective function. The highlighted values in the Table 2 are the higher and the lower values of each parameter that were found by the SMC algorithm.

It was observed that when the SMC increases the QB non-biased weight, BR remains in a higher range of values since QB keeps in constant growth. At this time, QB is still within a smaller range of values. When the QB switches to a higher range of values, BR tends to oscillate in a smaller range of values. In sum, the SMC algorithm tries to compensate the high compression of B slice (QB) by a lower bitrate (BR) and vice versa. This contributes for a better image quality.

The experiment 1 done with the FR, QP and PF parameters confirmed the conclusions obtained in the experiments with BR, QI and QB parameters that were described in this section.

4.2 Results of the Second Experiment

In graph 1 (Figure 4), that shows the results obtained in the experiment 2, it is observed the behavior of the QI, QP, QB, and PF parameters when the BR is not considered in the objective function.

The parameters kept the same behavior of the experiment 1. However, the higher and the lower values of the QI, QP and QB parameters that are shown in Table 3, were increased if compared with the values of the Table 1 (experiment 1).

The range of the values of QI, QP, and QP increased because the BR parameter was not considered (its weight have been set to zero) in the objective function of the experiment 2. In sum, the BR parameter influences the limits of these parameters (Kim et al., 2005).

In graph 2 (Figure 4), it is shown the curves of OF and FR parameters in the experiment 2. The OF parameter tends to fluctuate until the iteration 7. After this interaction it stabilizes in lower values than the values obtained in the experiment 1, which means a lower quality image.

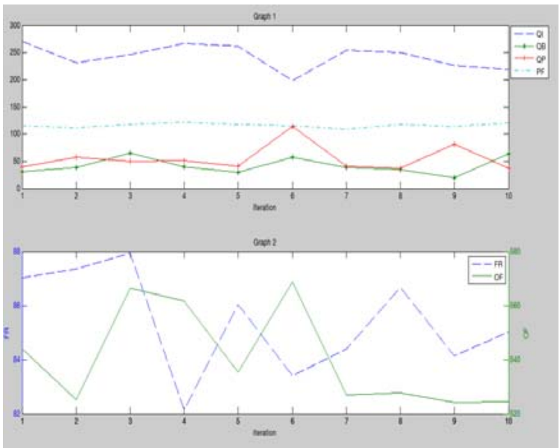

Figure 4: Graphs 1 and 2 of the Experiment 2 using BR parameter.

The point is that BR is an important parameter in the objective function. When the BR parameter is considered in this function (experiment 1), it tends to increase the OF value and contributes for a better image quality. When the BR parameter is not considered in the OF (Experiment 2), the quantization parameters (QI, QP, QB) assume higher values that contribute for a worse image quality.

In Graph 2 (Figure 4) was observed that FR tends to fluctuate because BR was not considered in the objective function. The BR directly influences the FR parameter and when the BR is not considered the FR fluctuates.

Table 3: Mean values of the experiment 2 not considering the BR parameter.

Iteration	AV OF	AV BR	AV FR	AV QI	AV QP	AV QB	AV PF
1	543.94	0.00	87.03	270.46	39.65	30.91	115.90
2	525.29	0.00	87.36	230.70	57.09	38.31	111.83
3	566.52	0.00	87.93	245.95	49.45	65.26	117.93
4	561.73	0.00	82.14	266.50	51.15	39.93	122.00
5	535.39	0.00	86.05	261.62	40.42	29.36	117.93
6	568.79	0.00	83.41	198.08	113.94	57.46	115.90
7	526.99	0.00	84.40	253.52	40.98	38.48	109.60
8	527.69	0.00	86.66	250.48	37.70	34.91	117.93
9	524.27	0.00	84.15	226.81	80.85	19.01	113.46
10	524.51	0.00	85.03	218.64	37.73	63.14	119.97

In this experiment the standard deviations of the FR and PF mean values reached a low standard deviation while the QI, QP and QB reached a higher value. These standard deviations reflected in the objective function standard deviation.

The experiment 2 done with the FR, QP, QB, QI and PF parameters confirmed the conclusions obtained in the experiments with BR that was described in this section.

5 CONCLUSIONS

It was presented a new hybrid algorithm called Simulator of Metaheuristics applied to a CODEC (SMC). The SMC uses two metaheuristics: Tabu Search and Genetic Algorithm. It is used to identify the best configuration to a CODEC H.264 for the Brazilian Digital Television System (BDTS) by using six parameters: BR, FR, QI, QP, QB and PF. The model proposed in this paper was accurate. The parameters behavior was according to the literature. The experiments proved that the SMC algorithm tries to improve the H.264 configuration through the best combination of the six studied parameters. The SMC algorithm proved to be robust and reliable. The SMC algorithm takes just four minutes to have 300 executions. It was developed in ANSI C language and it was run in an Intel Core 2 Duo processor.

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