CHAPTER VI

SIMULATION RESULTS AND ANALYSIS

The simulation results of AOSH and AOCSH search algorithm with tangent weighted trade-off function for the motion estimation in the H.264/AVC video compression standards have discussed in this chapter.

The characteristics of the videos taken for the simulation are given in Table 6.1. The time frame, macro block sizes etc., of the entire videos taken for the validation are with the same entity for the ease of the simulation.

Table 6.1: Characteristics of Input Videos

Videos	**Time (sec)**	**Frame rate (frames per second)**	**Number of frames**	**Scalar value for Quantization**	**Macro block size**
Football	2	30	60	27	16*16
Garden	2	30	60	27	16*16
Tennis	2	30	60	27	16*16

6.1 PERFORMANCE OF VIDEO COMPRESSION

The performance evaluation metrics used for the analysis are: compression efficiency, Structural Similarity index (SSIM) [79, 97], PSNR and computation time.

The performance analysis of the AOSH and AOCSH method is compared to the existing standards: H.264/AVC standard [88], and elastic motion estimation method [68].

Compression efficiency:

The most obvious measure of the compression efficiency is the bit rate, which gives the average number of bits per stored pixel of the image is given by Equation (6.1),

$$\text{bit rate} = \text{(image width)*(image height)*(color depth)*(frame rate)} \quad (6.1)$$

In digital telecommunication, the bit rate is the number of bits that pass a given point in a telecommunication network in a given amount of time, usually a second. Thus, a bit rate is usually measured in some multiple of bits per second - for example, kilobits, or thousands of bits per second (Kbps). If the bit rate is very low, compression ratio might be a more practical measure, is given by Equation (6.2),

$$\text{Compression ratio} = \frac{\text{size of the original file}}{\text{size of the compressedfile}} \quad (6.2)$$

Structural Similarity Index:

The visual quality evaluation of the video after the compression is done using the SSIM metrics. The definition of the SSIM metric is given below by Equation (6.3).

$$SSIM(F_D, F_O) = \frac{(2 * M(F_D) * M(F_O) + C_1) * (2 * CV(F_D, F_O) + C_2)}{(M^2(F_D) + M^2(F_O) + C_1) * (V(F_D) + V(F_O) + C_2)} \quad (6.3)$$

Where, $M(F_D)$ is mean of decompressed frame F_D, $M(F_O)$ is mean of original frame F_O, $V(F_D)$ is variance of decompressed frame F_D, $V(F_O)$ is variance of original frame F_O, $CV(F_D, F_O)$ is co-variance of frames F_D and F_O, C_1 and C_2 are constants. The SSIM is used to evaluate the visual quality of the video after the decompression.

Distortion:

Distortion measures can be divided into two categories: subjective and objective measures. A distortion measure is said to be subjective, if the quality is evaluated by humans. The use of human analysts, however, is quite impractical and therefore rarely used. The weakest point of this method is the subjectivity at the first place. It is impossible to establish a single group of humans (preferably experts in the field) that everyone could consult to get a quality evaluation of their pictures. Moreover, the definition of distortion highly depends on the application, i.e. the best quality evaluation is not always made by people at all.

In the objective measures the distortion is calculated as the difference between the original and the reconstructed image by a predefined function. It is assumed that the original image is perfect. All changes are considered as occurrences of distortion, no matter how they appear to a human observer. The quantitative distortion of the reconstructed image is commonly measured by the mean absolute error, mean square error, and PSNR. The definition of the PSNR metric is given by Equation (6.4),

$$PSNR = 10log_{10} \frac{E_{max}^{2} \times I_{w} \times I_{h}}{\sum\sum\left(I_{xy} - I_{xy}^{*}\right)^{2}} \quad (6.4)$$

Where I_w and I_h are width and height of the image, I_{xy} is the original pixel value at coordinate (x, y), I_{xy}^{*} is the Decompressed pixel value at coordinate (x, y), $E_{\max}^{2}$ is the largest energy of the pixels (i.e., $E_{\max}$ =255 for 256 GLM). PSNR preserves the quality of the image frames.

6.2 SIMULATION RESULTS OF AOSH SEARCH METHOD

6.2.1 Performance evaluation of visual quality using SSIM

The evaluation of the visual quality of the proposed AOSH algorithm and trade-off criterion function using the structural similarity index as the metrics is discussed in this section. The analysis curve for the performance analysis is plotted between the bit rate and the SSIM value. The SSIM is taken for the two bitrates in the simulation: 1.4Mbits/sec and 2.8 Mbits/sec. The performance of the AOSH system is compared with the H.264/AVC video compression standard [100, 101] and elastic motion estimation for video coding [79]. The analysis graphs for the three videos taken for the simulation are specified discretely.

i) Football video:

The performance evaluation curve of the football video is shown in Figure 6.1. For the lower bit rate of 1.4Mbits/sec, the SSIM value attained by the AOSH method is 0.9298 whereas the H.264/AVC achieved the SSIM value of 0.6895 and the elastic method achieved the value of 0.64. The SSIM value of the AOSH method is 0.2403 greater than the H.264 standard and 0.2898 greater than the elastic method. The increase in the bit-rate increases the value of the SSIM. The increase in the bit-rate for about 2.8Mbits/sec from 1.4 Mbits/sec, increases the SSIM value of the AOSH and weighted tangent trade-off function based compression algorithm by 0.0067 i.e.,0.9365 and is shown in Figure 6.1.

But the H.264/AVC standard attained the SSIM value of 0.64 which is 0.2843 less than the proposed method and the elastic method has attained the SSIM value of 0.65 which is 0.2943 less than the AOSH method. From the analysis curve, it is clear that the

AOSH method obtained increased SSIM value compared to the existing video compression standards and algorithms.

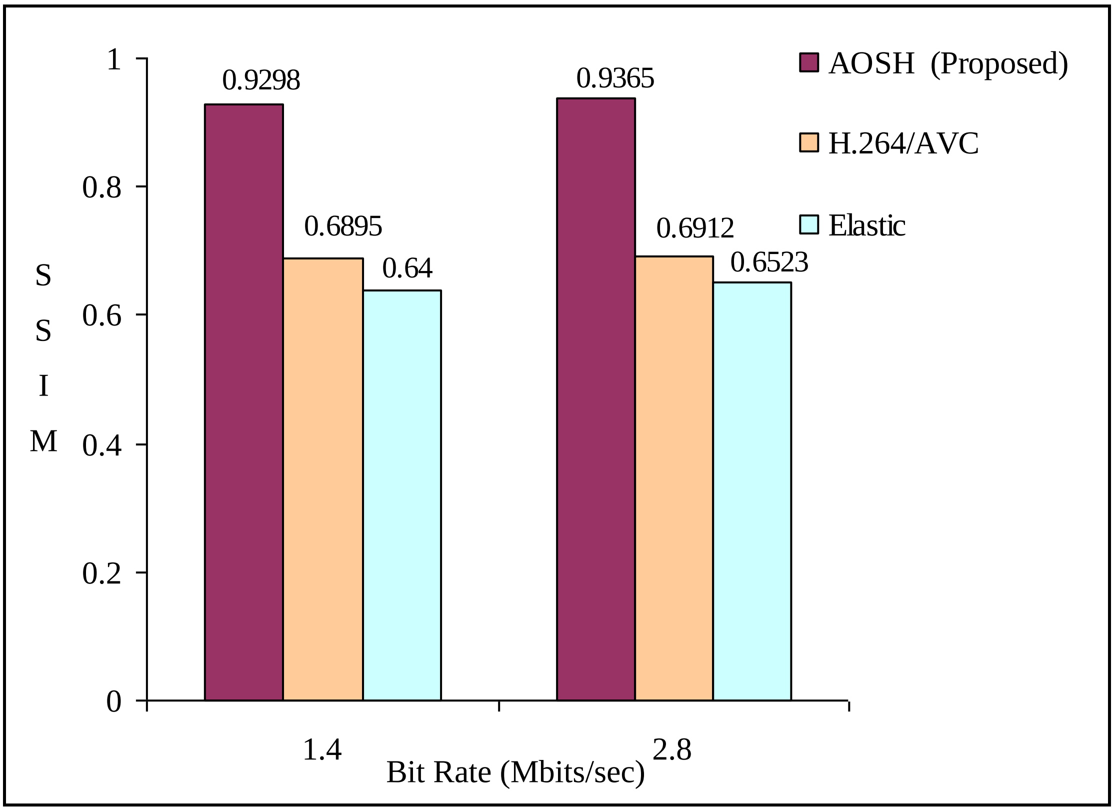

Figure 6.1: SSIM Graph for Football Video

For the football video, the increase in the similarity index value over the existing compression standards H.264/AVC and elastic motion estimation method proves the fact that the visual quality degradation of the compressed frame from the original frame is less for the AOSH method.

ii) Garden video:

Figure 6.2 represents the performance analysis curve of the garden video. The analysis curve is drawn between the SSIM and the bit rate. The SSIM for the evaluation of the compression standards is taken in two bitrates: 1.4 and 2.8Mbits/sec.

In lower bit rate i.e., 1.4 Mbits/sec, the SSIM attained by the elastic method and H.264/AVC for the garden video are 0.74 and 0.76 respectively. The AOSH method obtained the SSIM value of 0.9725 which is 0.2125 greater than that of the H.264/AVC standard and 0.2325 greater than that of elastic motion estimation method.

In the higher bit rate i.e. 2.8 Mbits/sec, the SSIM value reached by the AOSH method is 0.98 whereas the H.264/AVC and Elastic method attained the value of 0.786 and

0.752 respectively. The SSIM obtained for the AOSH, is higher than that of the existing H.264/AVC and elastic video compression standards. From the analysis curve, it is clear that the AOSH method ensures the visual quality of the video sequence and the compression performance of the compression algorithm.

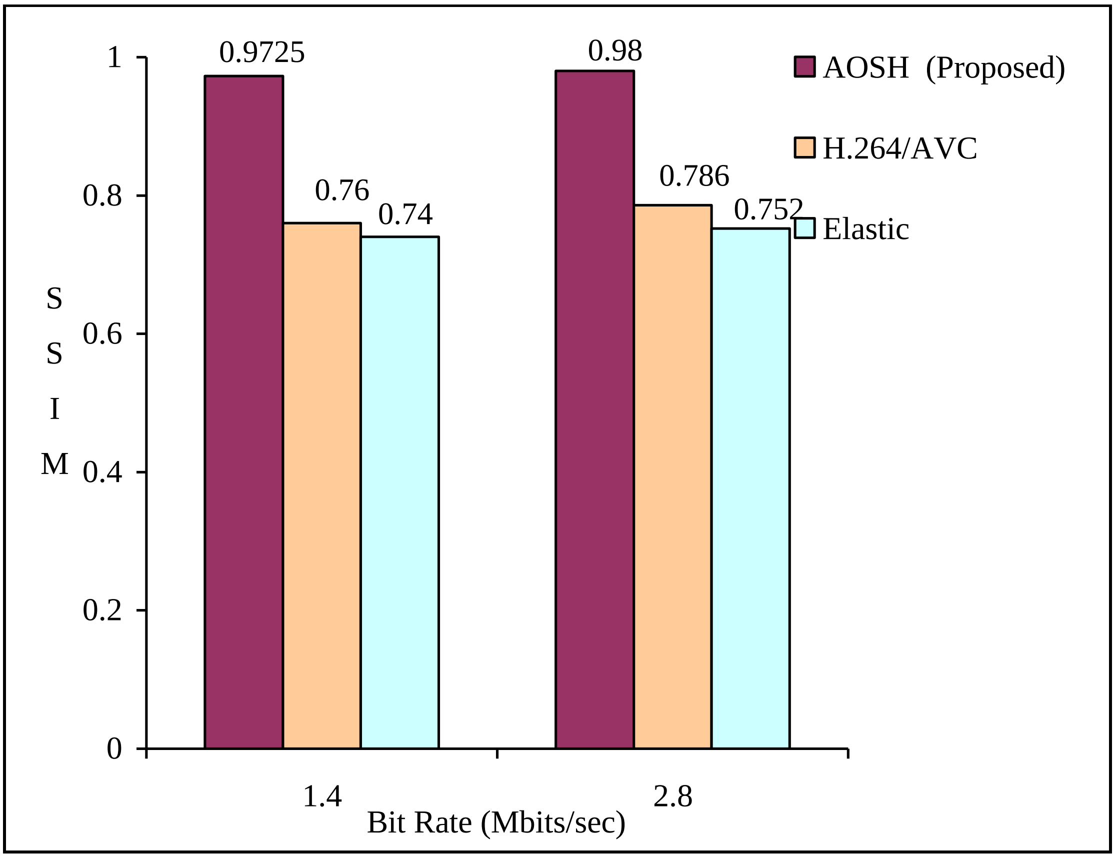

Figure 6.2: SSIM Graph for Garden Video

iii) Tennis video:

The performance evaluation curve of the tennis video is shown in Figure 6.3. For the 1.4 Mbits/sec bit rate, as shown in SSIM graph Figure 6.3, the value of the SSIM achieved by the AOSH algorithm is 0.9378. But the existing algorithms H.264/AVC and Elastic method attained the SSIM value of 0.8464 and 0.8134 respectively. The increase in the bit rate from 1.4 Mbits/sec to the 2.8 Mbits/sec attains the SSIM value of the AOSH method and existing method as 0.951, 0.853 and 0.827. From the SSIM graph of the tennis video, it is clear that the AOSH method shows better performance in terms of the visual quality.

From the performance analysis discussion based on the SSIM metrics, the fact is evident that the AOSH search algorithm showed better results in the compression procedure in terms of the visual quality and the compression performance.

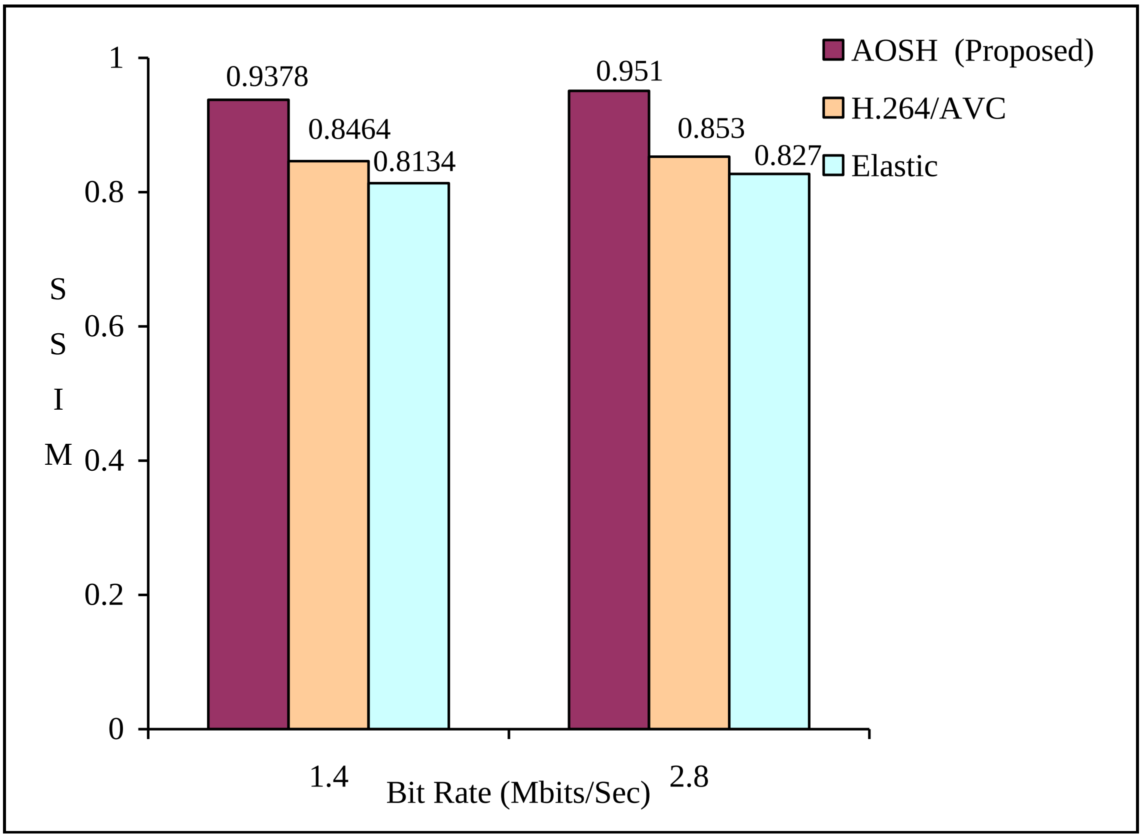

Figure 6.3: SSIM Graph for Tennis Video

iv) Comparison table:

The comparison table of the AOSH method and the existing video compression standards denoting the difference in the SSIM value over different bit rates are given below in Table 6.2a and Table 6.2b.

Table 6.2: SSIM Comparison Table

(a) Bit Rate=1.4 Mbits/Sec

Videos	**SSIM**		
	Proposed Method	**Existing Methods**	
	AOSH	**H.264/AVC**	**Elastic Motion Estimation**
Football	0.9295	0.6895	0.64
Garden	0.9725	0.76	0.74
Tennis	0.9378	0.8464	0.8134

(b) Bit Rate=2.8 Mbits/Sec

Videos	SSIM		
	Proposed Method	Existing Methods	
	AOSH	H.264/AVC	Elastic Motion Estimation
Football	0.9365	0.6912	0.6523
Garden	0.98	0.786	0.752
Tennis	0.951	0.853	0.827

From the SSIM comparison table, it is clear that the AOSH and tangent weighted trade-off function based video compression algorithm attains maximum SSIM value for all the three videos taken for the simulation, thereby proving the efficiency of the AOSH method.

6.2.2 Performance evaluation using PSNR

This section presents the performance of the proposed AOSH algorithm using the parameter called, PSNR with respect to H.264/AVC and elastic method.

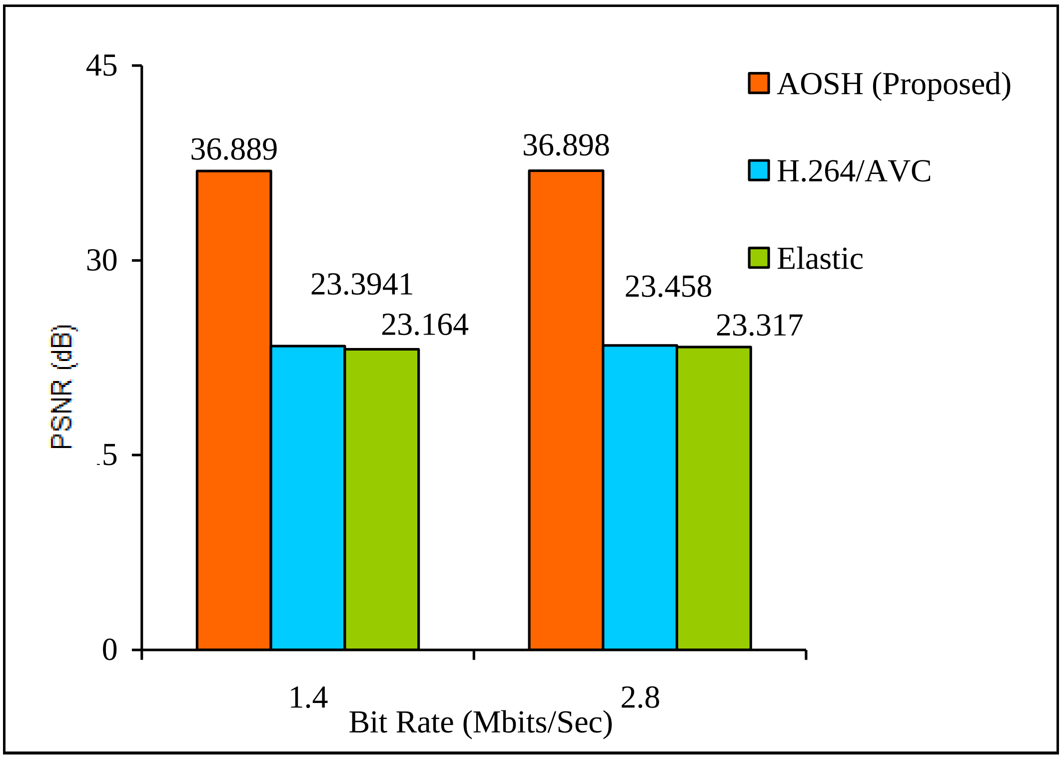

Figure 6.4: PSNR Graph for Football Video

Figure 6.4 shows the PSNR graph for football video. Here, the proposed AOSH algorithm achieved 36.889dB and 36.898dB for lower and higher bit rates respectively but the H.264 shows the values of 23.3941dB, 23.458dB and elastic method show the values of 23.164dB, 23.317dB.

In garden video, the proposed AOSH algorithm obtained the PSNR value of 36.88dB for lower bit rate and 38.42dB for higher bit rate as shown in Figure 6.5.

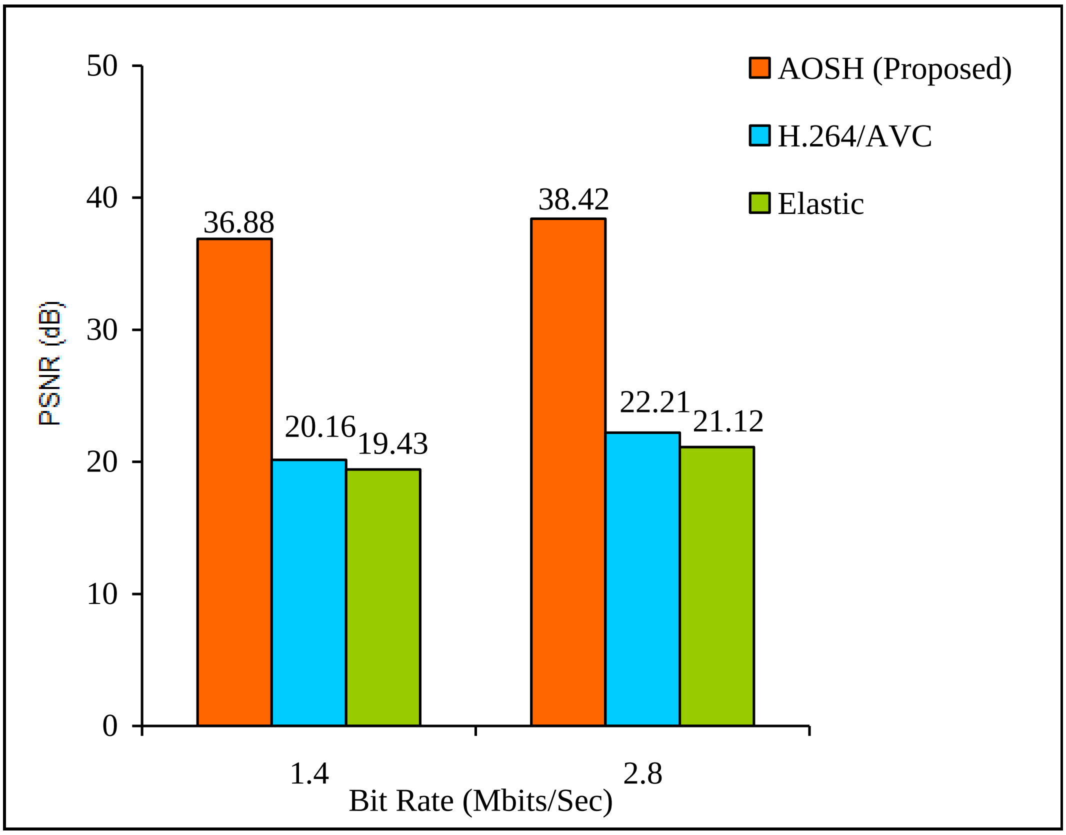

Figure 6.5: PSNR Graph for Garden Video

The H.264 model obtained 20.16dB and 22.21dB for lower and higher bit rates. The elastic method reached 19.43dB and 21.12dB for lower and higher bit rates respectively. This ensures that the proposed AOSH model shows the better performance than the existing algorithms in terms of visual performance.

Figure 6.6 shows the PSNR graph for tennis video. Here, the proposed AOSH algorithm, H.264/AVC and elastic method obtained the values of 36.89dB, 23.24dB and 22.51dB respectively in terms of PSNR for lower bit rate. From the analysis, we clearly understand that the proposed AOSH algorithm is better for video compression than the existing algorithms taken for comparison.

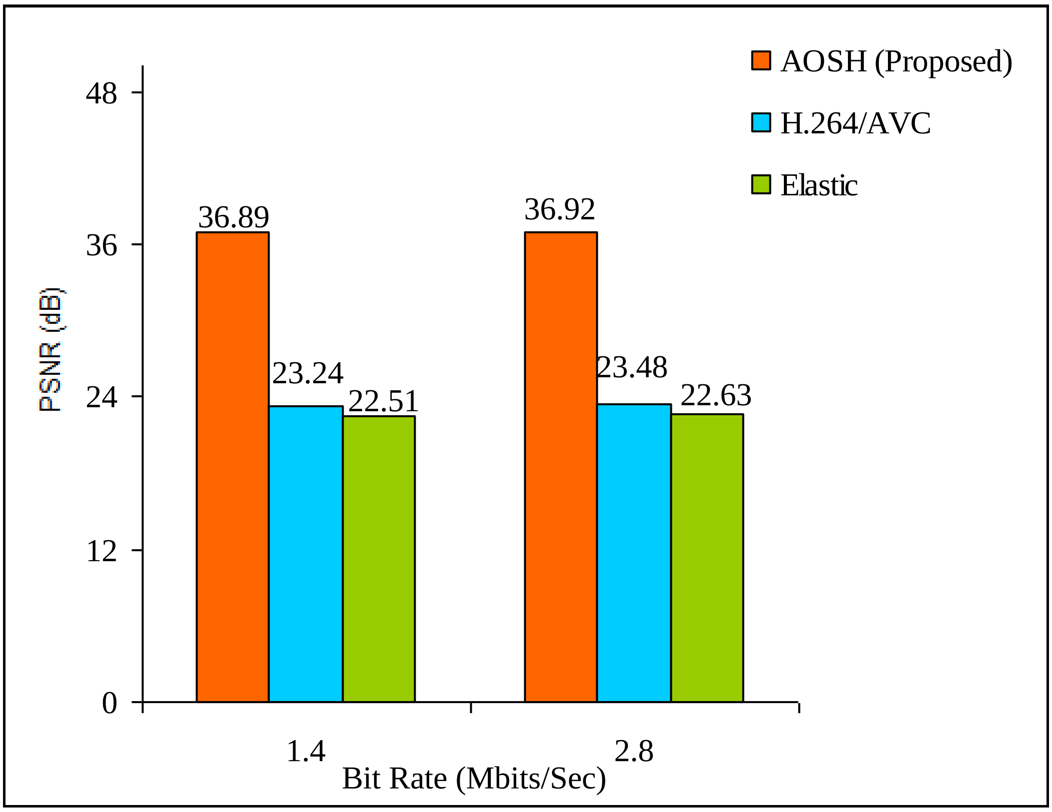

Figure 6.6: PSNR Graph for Tennis Video

In chapter 6.2, simulation results of an adaptive order search algorithm and tangent weighted trade-off function for motion estimation in the H.264/AVC video compression standard were presented. The adaptive order search algorithm AOSH is developed by integrating the square and hexagon search algorithms for an adaptive order of the depth. The size of the search pattern i.e., both the square and hexagon searches is chosen by the order value of the search. This AOSH search algorithm improves the searching capability of the motion estimation process with the high SSIM and PSNR. In addition to the search algorithm, the tangent weighted trade-off function was designed to evaluate the search points resulted from the search algorithm. The parameters considered for the trade-off function were rate and distortion. These two enhancements are applied to block estimation process to improve the visual quality as well as compressive performance.

The simulation of the AOSH method is performed using three videos namely, football, garden, and tennis. The performance of the AOSH method is compared to the H.264/AVC and elastic motion estimation method using the quantitative parameter SSIM and PSNR. The simulation results proved the effectiveness of the AOSH system with good improvement in the visual quality and the compressive performance.

6.3 SIMULATION RESULTS OF AOCSH SEARCH METHOD

The comparative discussion of the results obtained by the application of the proposed AOCSH algorithm in the video compression standard is discussed in this section. The performance analysis of the AOCSH method is compared to the existing standards: AOSH method, H.264/AVC standard [88], and elastic motion estimation method [68]. The performance evaluation metrics used for the analysis are: SSIM [79], PSNR and computation time.

6.3.1. Performance evaluation using SSIM

The performance evaluation of the proposed AOCSH algorithm based on the SSIM evaluation metrics is discussed in this section. The SSIM analysis curve is plotted between the SSIM values and the bit rate. The SSIM value is taken for the two bit rate 1.4 Mbits/sec and 2.8 Mbits/sec for the comparative purpose. The SSIM value should be maximal for the efficient video compression standard.

i) Football video:

The SSIM analysis curve for the football video is shown in Figure 6.7. The value of SSIM attained by the AOCSH is higher than the existing methods for the football video at a bit rate 1.4 Mbits/sec and the 2.8 Mbits/sec. From the graph, it is clear that the SSIM value of the AOCSH algorithm is higher.

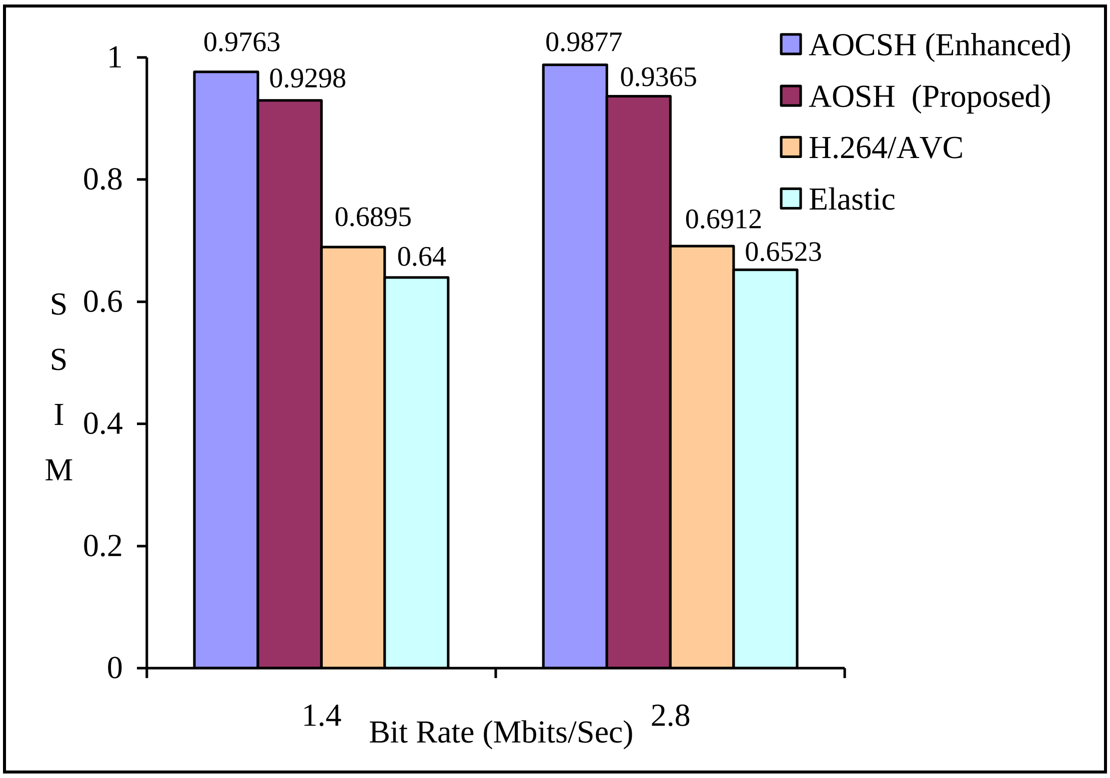

Figure 6.7: SSIM Analysis Curve for Football Video

The value of the SSIM attained by the proposed AOCSH algorithm is 0.9763, whereas the existing standards H.264/AVC and elastic model acquired the SSIM value of 0.6895. But the value of SSIM for the AOSH algorithm is 0.9298. The AOCSH algorithm attained the SSIM value of 0.2908 which is greater than the existing standard. This proves the improved compression because of the AOCSH algorithm on the football video.

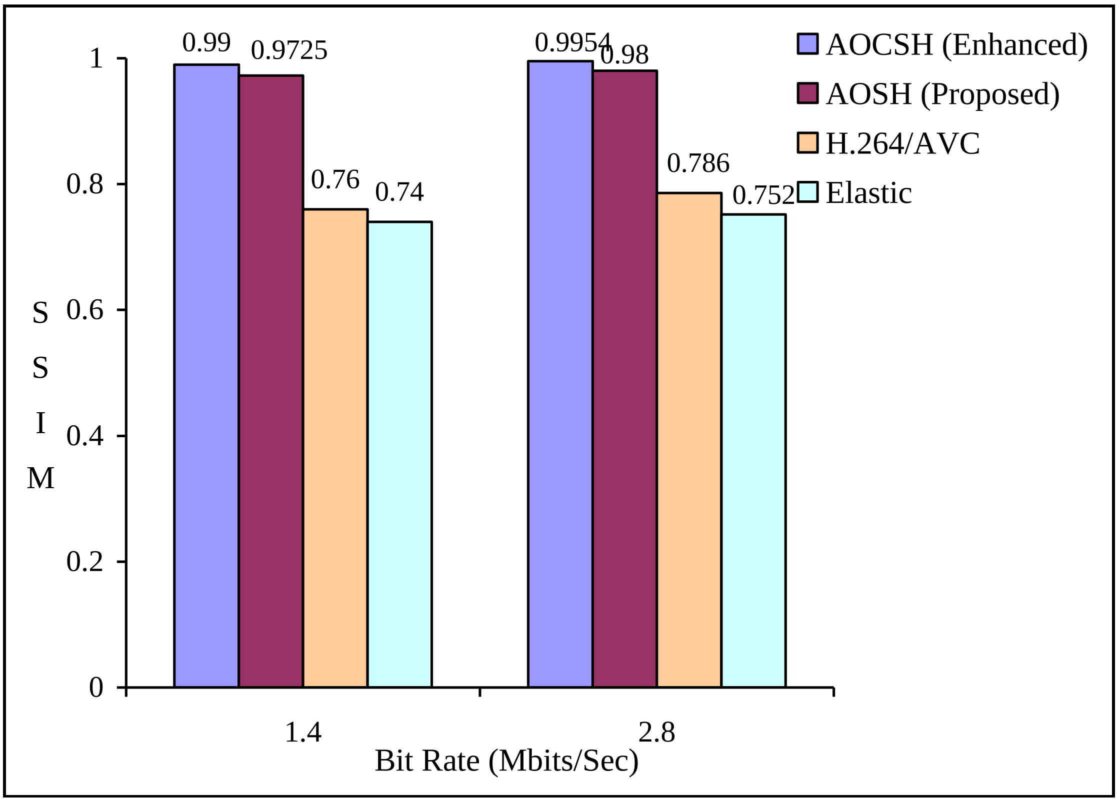

Figure 6.8: SSIM Analysis Curve for Garden Video

ii) Garden video:

Figure 6.8 shows the SSIM analysis curve of the garden video. For the bit rate 1.4 Mbits/sec and 2.8 Mbits/sec, the SSIM value of the AOCSH algorithm is 0.99 and 0.9954. The value of the SSIM for the AOSH algorithm is 0.9725 and 0.98 which is less than the AOCSH algorithm. The H.264/AVC standard and the elastic model have attained the SSIM values of 0.76; 0.786 and 0.74; 0.752 respectively, which is less than the AOCSH algorithm. From the graph, it is clear that the AOCSH algorithm reached maximum SSIM value compared to the existing video compression standards.

iii) Tennis video:

The SSIM analysis curve for the tennis video is shown in Figure 6.9. The SSIM value for the bit rate of 1.4 Mbits/sec for the AOCSH algorithm, AOSH algorithm, and the existing standards; H.264/AVC and the elastic model are 0.9847, 0.9378, 0.8464 and 0.8134 respectively. On comparing the attained SSIM value, the value of the AOCSH system is higher. The SSIM values for the 2.8 Mbits/sec bit rate is 0.989, 0.951, 0.853 and 0.827 respectively. The value of the SSIM in the tennis video is 0.1713 and is higher than that of the existing compression standards.

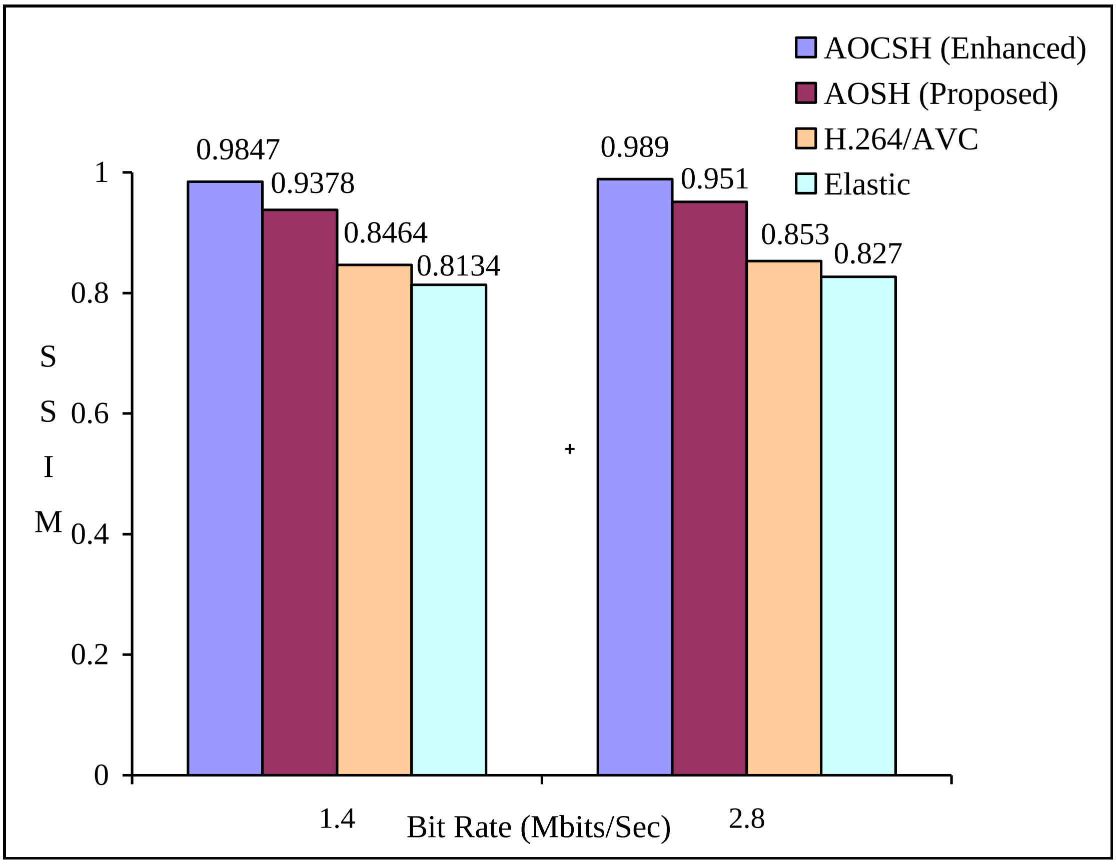

Figure 6.9: SSIM Analysis Curve for Tennis Video

6.3.2. Performance evaluation using PSNR

The performance evaluation of the videos taken for the simulation based on the PSNR metric is discussed in this section. The PSNR analysis curve is plotted between the peak signal to the noise ratio value and bit rate. In the simulation, the PSNR values for the comparative analysis of the video compression methods are taken at two bitrates; 1.4 Mbits/sec and 2.8 Mbits/sec. The PSNR value should be maximal for the better compression performance.

i) Football video:

The PSNR analysis curve for the football video is shown in Figure 6.10. At bit rate 1.4 Mbits/sec, the PSNR value attained by the AOCSH is 38.733%. On comparing the PSNR value of the methods considered for the analysis, the maximum PSNR value is attained by the AOCSH method. The values of the PSNR for comparative methods, AOSH, H.264/AVC and elastic method are 36.889%, 23.394%, and 23.164% respectively. This proves the fact that the AOCSH algorithm is well suitable one for compression standards with the optimized performance.

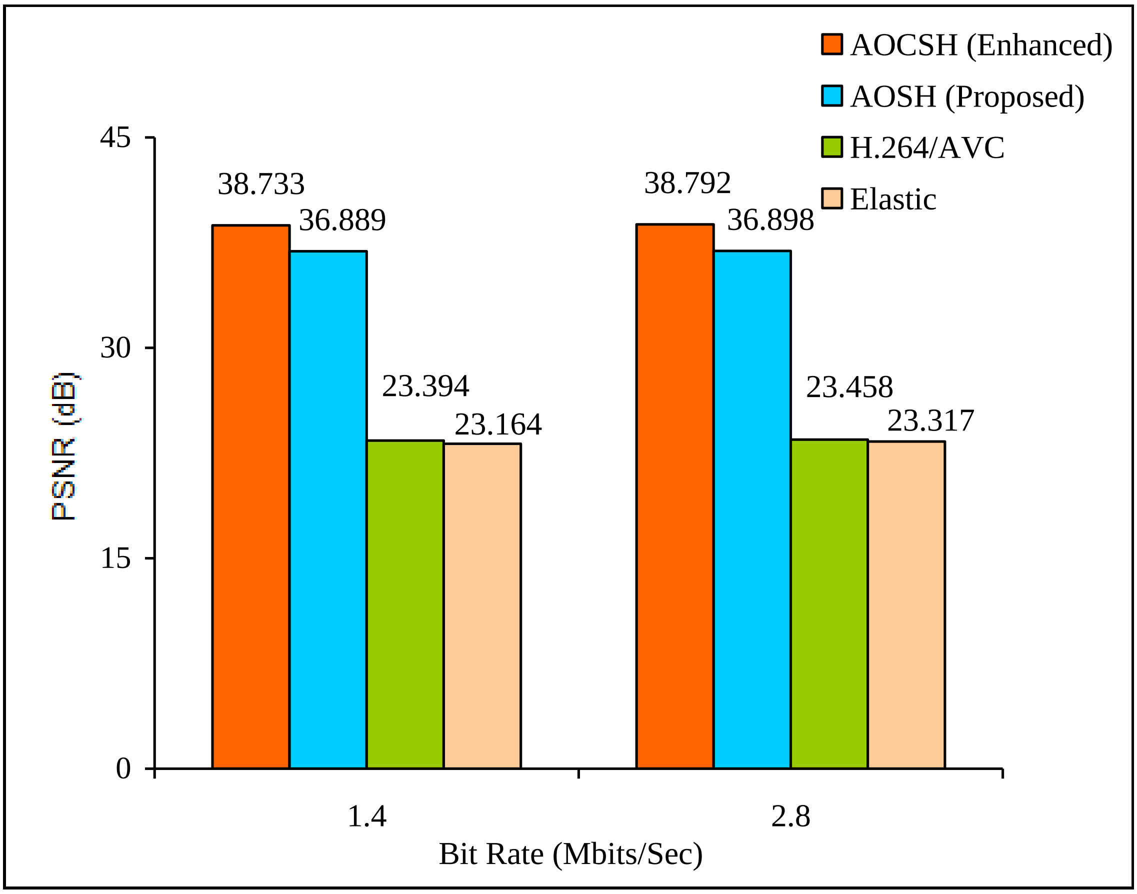

Figure 6.10: PSNR Analysis Curve for Football Video

At bit rate 2.8 Mbits/sec, the PSNR value attained by the AOCSH and the existing methods are 38.792dB, 36.898dB, 23.458dB and 23.317dB respectively.

ii) Garden video:

Figure 6.11 represents the PSNR analysis curve of the garden video. For 1.4 Mbits/sec bit rate, the value of the PSNR achieved by the AOCSH method is 38.711% which is 1.83% greater than that of PSNR value of AOSH method, and 18.55% greater than that of H.264 standard and 19.28% greater than that of the elastic method. Similarly, for the bit rate 2.8 Mbits/sec, the PSNR value attained by the AOCSH method is higher than that of the existing video compression standards. For the garden video, the PSNR value of the AOCSH method is higher than that of the existing standards proving the efficacy of the AOCSH method in the video compression.

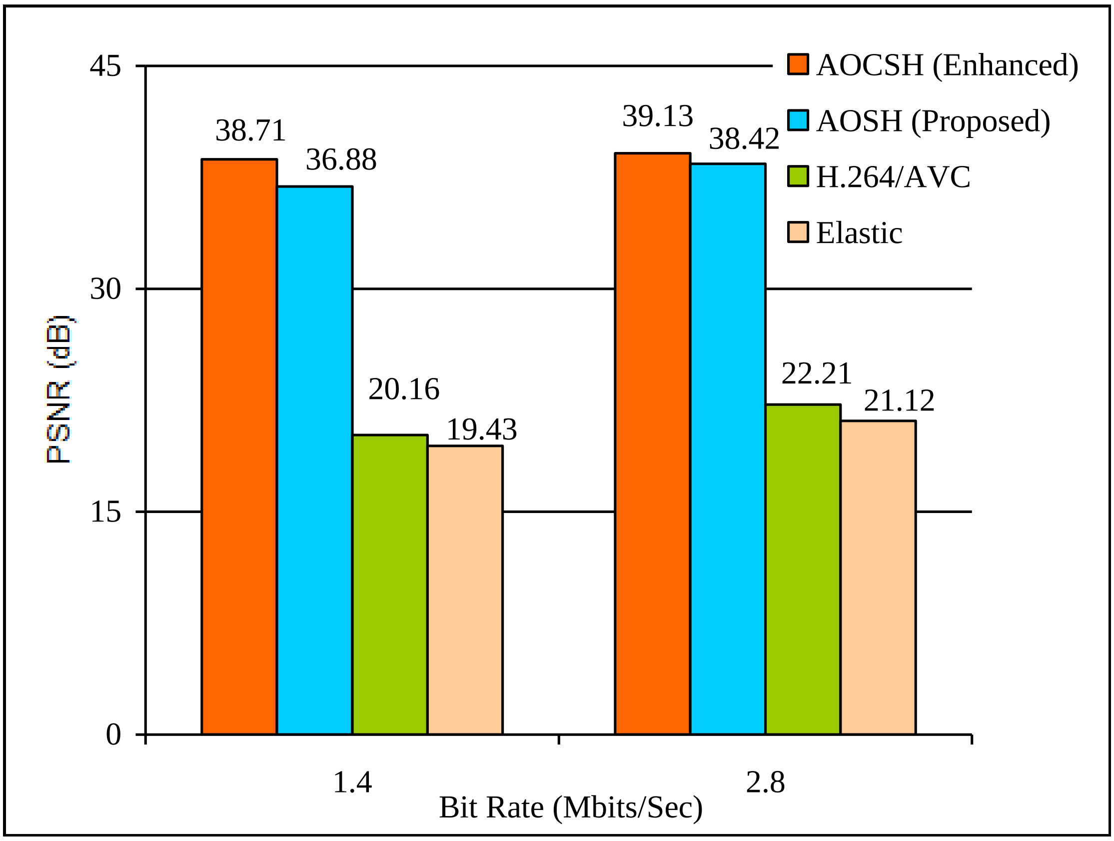

Figure 6.11: PSNR Analysis Curve for Garden Video

iii) Tennis video:

The PSNR analysis curve of the tennis video taken for the simulation is shown in Figure 6.12. The experimental results viewed up for the bit rate 1.4 Mbits/sec, specify the fact that AOCSH method reached the maximum PSNR value. At the bit rate 1.4 Mbits/sec, the values of the PSNR acquired by the AOCSH algorithm and the existing algorithms; AOSH, H.264/AVC and elastic methods are 38.73dB, 36.89dB, 23.24dB, and 22.51dB respectively.

The PSNR value of the AOCSH is 15.49% and 16.22% higher than the existing algorithms H.264/AVC and elastic methods respectively. For the bit rate 2.8 Mbits/sec, the PSNR value is maximal for the AOCSH method. From the SSIM and the PSNR evaluation curve, the AOCSH algorithm and Fuzzy tangent weighted function based motion estimation scheme in the video compression standard proves to be more effectual than the existing algorithms without any compromise with the visual quality of the video. The AOCSH compression standard results in the bit stream generation with the reduced bits for storage abetting in the superior compression applications.

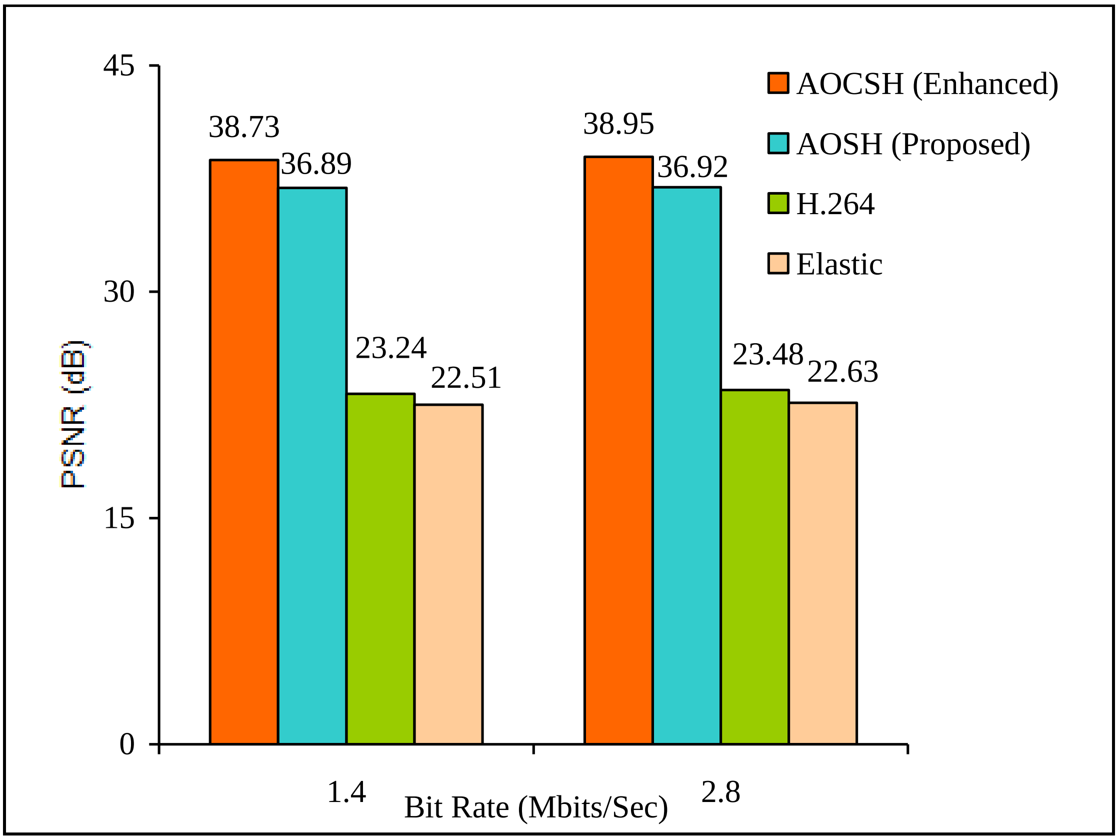

Figure 6.12: PSNR Analysis Curve for Tennis Video`

6.4 SAMPLE AND DECOMPRESSED FRAMES

The sample frames from the three different videos football, garden and tennis are shown in Figure 6.13a, Figure 6.14a, and Figure 6.15a specifies the sample image frames of the video sequence football, garden and tennis respectively.

The decompressed frames of the sample frames after the simulation of the three videos football, garden and tennis are shown in Figure 6.13b, Figure 6.14b, and Figure 6.15b respectively.

The original and the decompressed videos are having more similar visualization and there is not much visual degradation for the human visual system.

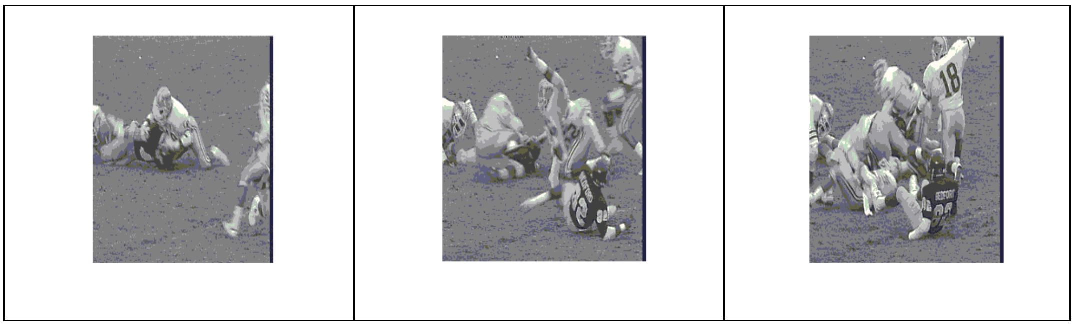

Figure 6.13a: Sample Frames of Football Video

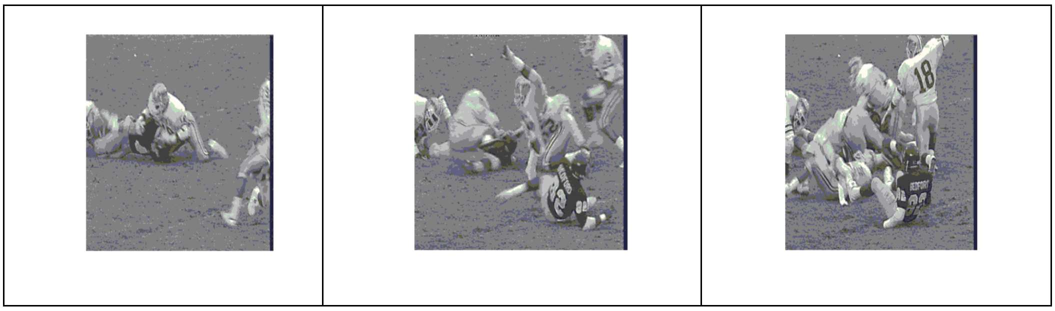

Figure 6.13b: Decompressed Frames of Football Video

Figure 6.14a: Sample Frames of Garden Video

Figure 6.14b: Decompressed Frames of Garden Video

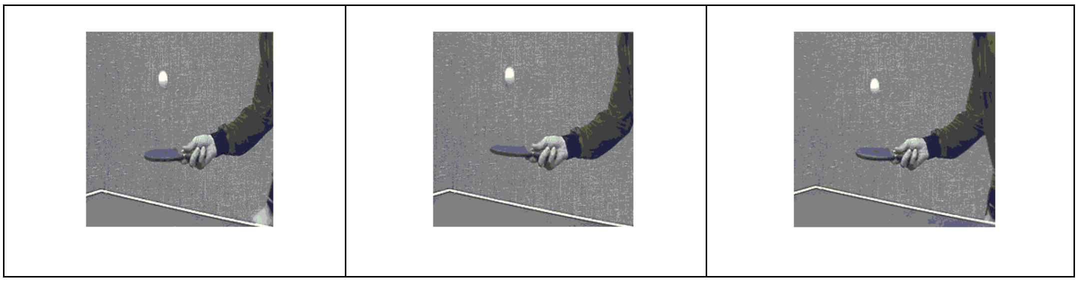

Figure 6.15a: Sample Frames of Tennis Video

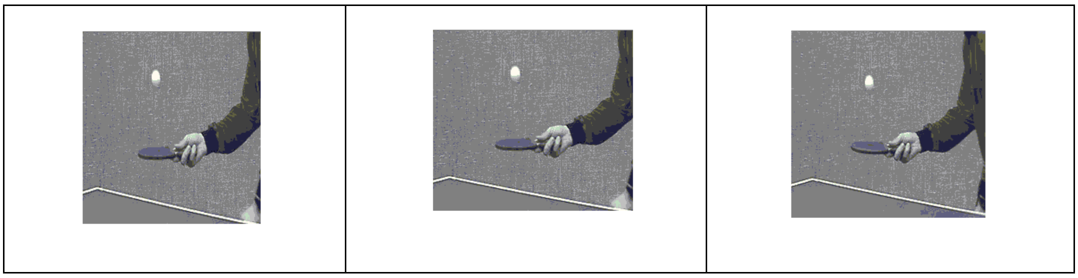

Figure 6.15b: Decompressed Frames of Tennis Video

6.5 COMPUTATION TIME ANALYSIS

In this section, the performance analysis based on computation time (in sec) in all the four techniques for the five videos with varied bit rates is shown in Figure 6.16a and Figure 6.16b.

For the football video, when the bit rate is 1.4 Mbits/sec, AOSH, elastic model, and H.264, take computation time of 5.13 sec, 7.83 sec and 9.23 sec, whereas, in AOCSH, it is 4.33 sec. In the same video, for the bit rate 2.8 Mbits/sec, the computation time required in AOCSH is 4.01 sec, whereas the minimum time taken among the four techniques is 5.83 sec, by AOSH approach. For the garden video, the minimum time taken for the computation by AOCSH is 5.56 sec, when the bit rate is 2.8 Mbits/sec. Meanwhile, AOSH, elastic model and H.264 have the computation time of 6.74 sec, 12.61 sec, and 15.56 sec.

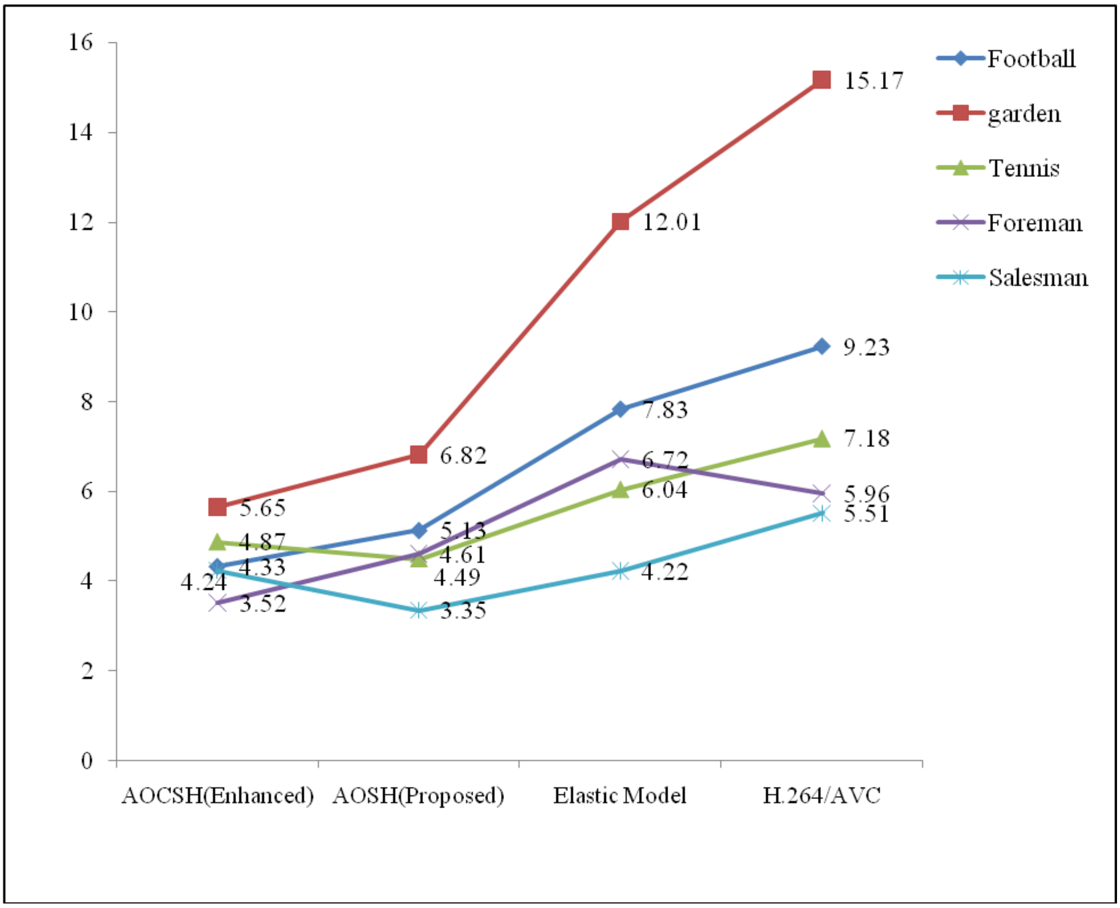

Figure 6.16a: Computation Time Analysis when the Bit Rate 1.4 Mbits/sec

The minimum computation time observed by AOCSH, for the foreman video is 3.28 sec, when the bit rate is 2.8 Mbits/sec, while AOSH, elastic model and H.264 has 3.74 sec, 4.77 sec, and 6.62 sec. Thus, from the computational time analysis, it is seen that the proposed AOCSH approach has better performance, as it has the least computation time in most of the cases.

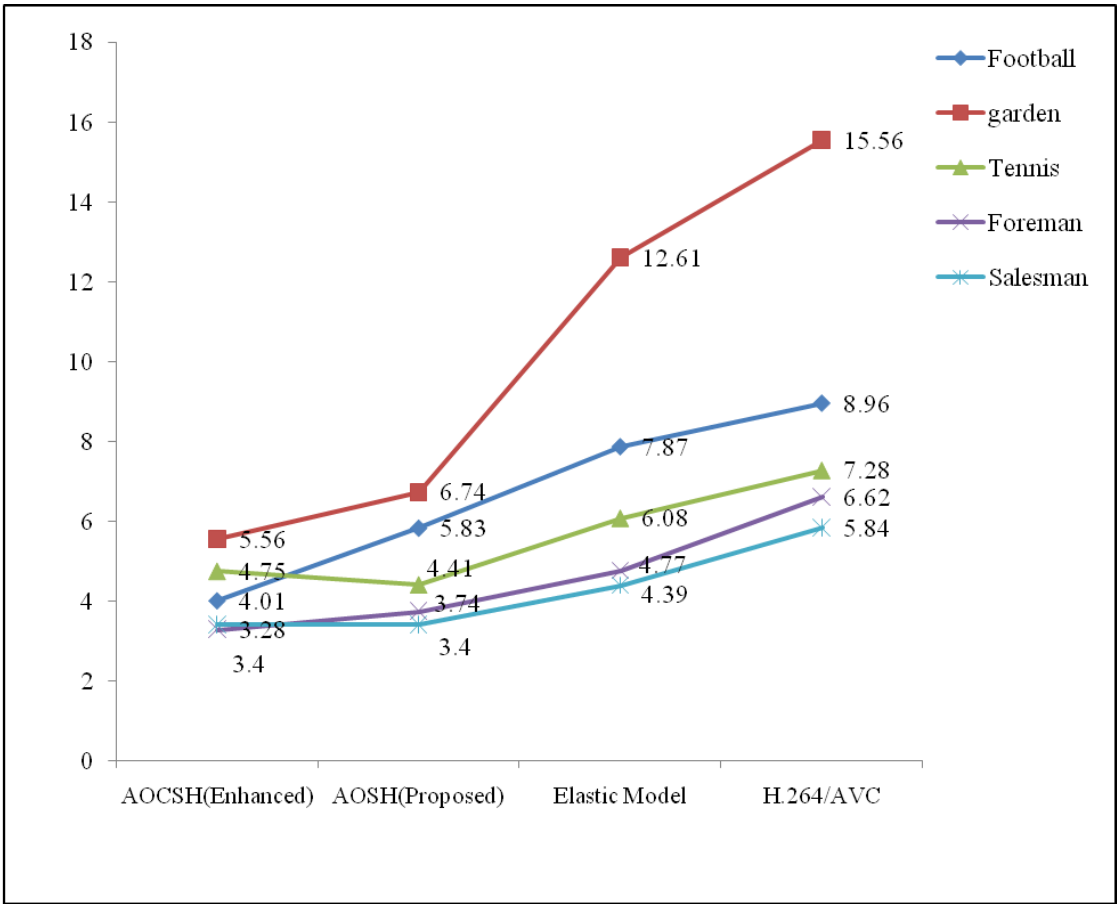

Figure 6.16b: Computation Time Analysis when the Bit Rate 1.4 Mbits/sec

6.6 SUMMARY

In this chapter, simulation results of an AOSH and AOCSH search algorithms with and fuzzy tangent weighted trade-off function for the motion estimation in the H.264/AVC video compression standards are presented. The AOCSH motion estimation algorithm incorporates the search algorithms; cross, square and hexagon search. The directional cross search and adaptive order square and hexagon search improve the searching capability of the searching algorithm with the improved searching time, less computation complexity and reduced number of search points. This improves the compression performance in the H.264/AVC standard. Also, the fuzzy tangent weighted function was used to assess the searching points using two parameters called, rate and distortion. The adaptation of the AOCSH search algorithm and the trade-off function to the block estimation process of the H.264/AVC video compression standard improves the visual quality as well as compressive performance.

The efficiency of the AOCSH algorithm has experimented in three videos namely, football, garden and tennis and compared over the H.264/AVC method and the elastic motion estimation method. The performance evaluation was done using the performance metrics; SSIM, PSNR, compression efficiency and computation time. The AOCSH and fuzzy tangent weighted trade-off function based motion estimation resulted in the video compression with good improvement in the compression performance with the solid visual quality comparing to the existing video compression methods.