CHAPTER V

DEVELOPMENT OF ADAPTIVE ORDER CROSS-SQUARE-HEXAGONAL SEARCH AND FUZZY TANGENT WEIGHTED TRADE-OFF FOR MOTION ESTIMATION IN H.264/AVC

5.1 INTRODUCTION

Innovation in the field of mobile communication devices is increasing massively. The devices conveyed with the communications like mobile phone, note book etc., must have the knack for the execution of the complex multimedia applications. Video compression is the important unit to be considered in the development of technology associated with, mobile communication, the internet etc. In the mobile phone i.e., for any portable devices, the transmission of the video must be done with less bandwidth and the reception of the video must be done with less storage in the portable device. This objective in the video transfer can be attained by the proper video compression or video coding technique.

In general, the video sequence is the sequence of image frames. The image frame sequence is inter-related along the spatial and temporal dimensions. When the camera or an object moves in the field of the video sequence, the captured image frames also move. Due to this, a part of an image may appear in the multiple consecutive frames. The location of the analogous part is different from the original location but it is somewhat closer to the original location. The compression of the video sequence can be done by making use of such analogous option. Motion estimation technique is the procedure adapted to detect the motion in the successive frames which are having similar motion movement. In motion estimation scheme, the motion movements are identified on the blocks of a frame. The motion detection is achieved by the matching criteria performed between the reference and the candidate block of the image frame. In the video compression, the reduction of the data responsible for the representation of the video frame is done. The redundant frames with the same image information are neglected without affecting the visual quality. The transmission of the video defines on the redundancy of the data and then its predictable properties are defined which predict the real data to be transmitted and the error between them are only transmitted.

There are several algorithms available for the video compression procedure. The algorithms vary from one another by the complexity of the compression procedure, compression performance etc. The motion estimation in the video compression algorithm is categorized broadly into four types; they are macro-block based motion estimation [80], pixel based motion estimation, object based motion estimation, and region based motion estimation [90]. Moreover, the motion estimation in the video compression algorithm based on the macro block is of several types based on the search algorithm used. Some of the search algorithms [106] used is FS, ES, TSS, NTSS, FSS, binary search, CS, HSSS. Because of the immense block matching algorithms available, block based motion estimation is considered to be more competent than the pixel, region or the object based motion estimation schemes.

Researchers have focused their effort on developing the motion prediction scheme with the low computational time, and visual quality. The search algorithm used in the motion estimation scheme must have the significant block matching strategy with the increased search speed and accuracy is the main objective of the motion estimation in the video compression algorithm. The searching of the motion movement in the video having high motion content suffers from the quality degradation [114]. Another considerable factor in the search algorithm is searching time. The searching time of the motion block increases with the number of search points. The important objectives for choosing the search algorithm in the video compression standard are the algorithm with fewer search points, persuading low computational complexity and improved compressive performance.

In this chapter, an adaptive search algorithm called AOCSH is proposed. The AOCSH search algorithm is the integration of the cross search, square search, and hexagonal search. The amalgamation of the multiple search algorithms reduces the number of search points used in the motion movement detection. In the AOCSH search algorithm, the direction for the motion estimation is ascertained by the cross search. On the direction identification defined by the cross search, the adaptive order square and hexagonal search are performed. The integrated utilization of the search pattern increases the searching speed of the motion estimation scheme. In addition, a fuzzy tangent weighted function is proposed for the evaluation of the matching points from the search point obtained using the search algorithm. The trade-off function of the matching criteria considers the rate and distortion as the parameters. After the selection of the search point with motion movement, the motion vectors are generated and the MV's are subjected to the transformation, quantization and the bits are generated using the CAVLC coding. The generated bits are stored and transmitted and at the destination side, the bits are decoded into the motion vectors, de-quantized and inverse transformed into the macro blocks and the extracted frames are integrated into the video sequence. These steps are done in the decompression procedure.

The main contributions of this chapter are as follows:

i. *AOCSH:*

   A new search algorithm, AOCSH search algorithms are developed, by integrating the cross, square and the hexagon searches. The direction of the search is identified using the cross search. The search in the cross-defined direction is performed using the adaptive order square and the hexagon search. The adaptive order chooses the size of the square and hexagon searches; thereby the block match detection is made easy with the less searching time and searching points.

ii. *Fuzzy tangent weighted trade-off criteria:*

   In addition to the AOCSH search algorithm, a fuzzy tangential-weighted and trade-off function is developed for the evaluation of the matching search points. The trade-off criterion considers two parameters: rate and distortion. By taking the fuzzy weighted function of the rate and the distortion parameters, the match points are evaluated. The evaluation of the search points containing the motion in the corresponding block using the fuzzy tangent weighted trade-off criteria reduces the complexity in the compression.

5.2 ADAPTIVE ORDER CROSS-SQUARE-HEXAGONAL SEARCH AND FUZZY TANGENT WEIGHTED TRADE-OFF FUNCTION FOR MOTION ESTIMATION IN H.264/AVC

The proposed AOCSH search and fuzzy tangent weighted trade-off criterion for the motion estimation in the H.264/AVC is discussed in this section. Figure 5.1 represents the overall block diagram of the AOCSH search algorithm and the fuzzy tangent weighted trade-off function for the motion estimation in the H.264/AVC.

Primarily, the video sequence to be compressed is taken as the input for the compression standard. The first step is the image frame extraction. The image frames from the video sequences are extracted. Frame extraction is followed by the slicing. In slicing, the image frames are split into the macro blocks. The blocks resulted out of the slicing are subjected to the hybrid search procedure. The hybrid search integrates the cross search, square search and hexagon searches. The direction of search for the motion estimation is identified using the cross search. The direction recognition reduces the use of the search points in the unwanted direction.

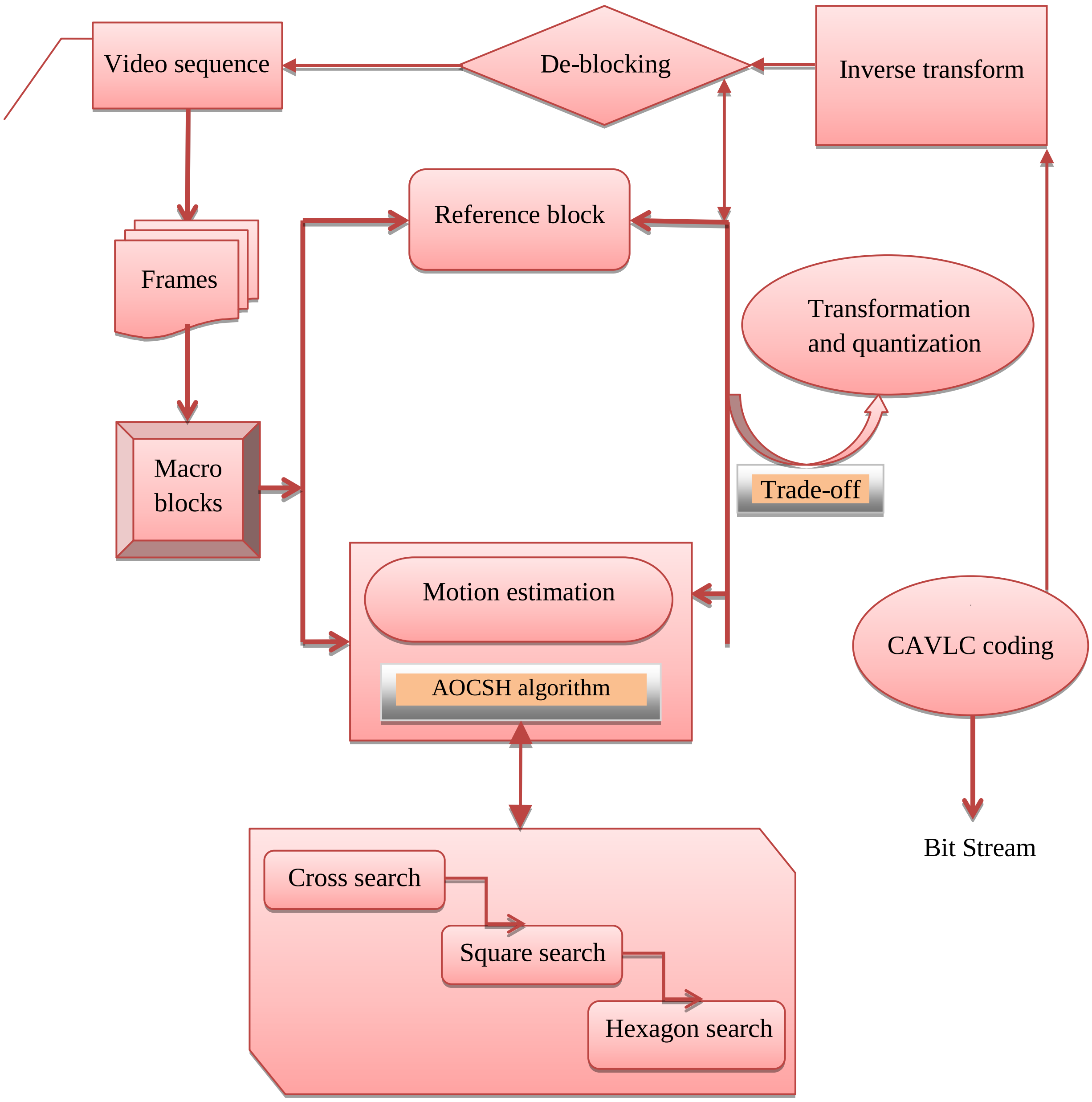

Figure 5.1: Overall Block Diagram of the AOCSH Motion Estimation Scheme

The direction enabled by the cross search may be in the horizontal or the vertical direction. Upon the direction discovered, the motion is searched using the square or the hexagonal search. The square or the hexagonal search is adaptive ones, in which the shape and size of the pattern depend on the order value. The square search detects the search point and the hexagonal search follows the search considering the square search detected points.

The availability of the best matching point with the reference is found on the characteristics of the proposed rate-distortion trade-off. The rate-distortion trade-off function is centred on the fuzzy tangent weighted function. The matching assessment using the trade-off function, results in the best searching point, for the motion vector generation. The generated motion vectors of the corresponding blocks are subjected to the transformation. Transformation is followed by the quantization, in which the coefficients ready for the coding process is generated. The encoding is done using the context adaptive variable length coding, which generates the bit streams. The compressed video results in the video data with fewer bits for the storage, making the video transmission easy for the portable devices as well as for the multimedia applications. The encoded bit streams are retrieved into the video sequence using the decompression procedure.

5.2.1 Search patterns used in the AOCSH

The search patterns used in the AOCSH motion estimation algorithm are discussed in this section. The search patterns utilized in the block matching algorithm are selected so as to stabilize the effect of one among the other. The search patterns in the AOCSH algorithm are:

i. Cross search,

ii. Square search and

iii. Hexagonal search.

The cross search identifies the direction of the search reducing the number of search points, the square search searches for the motion in the four possible directions, the hexagon search searches the motion in the sequence containing high motion movement as well as the discontinuities due to zooming, rotation etc. and the direction of the search increases more than that of the square search.

i. Cross search:

Initial search pattern used in the AOCSH algorithm is cross search. The structure of the cross search consists of five search points. The size of the cross search may vary according to the macro blocks size, but the searching point number will not alter. The direction of the motion in the macro blocks is found using the small cross search or the larger cross search.

Directional cross search:

The direction of the motion movement in the macro blocks onto which the motion estimation is done is set by the cross search. The first step in the cross search is initial search center prediction. The initial search center prediction can be performed easily, by the correlation of the neighbouring motion blocks [65]. After the center point prediction, the direction of the motion in the block is detected. The computational complexity reduction in the cross search is acquired by considering the current block with zero motion vectors. The cost of the block matching algorithm is considerably reduced by the adaptation of the cross search. The cost reduction is because of the early termination of the search for the optimal direction. By comparing the SAD value, the early termination of the search is attained. Based on the cross pattern utilized for the optimal direction of the search discovery, the size of the cross search varies. If the cross pattern is 2×2, the size of the cross search is small with four searching points, if the cross pattern is 4×4, the size of the cross search will be large. The cross search finds the direction of the motion estimation search by making use of the search point with the minimum SAD value.

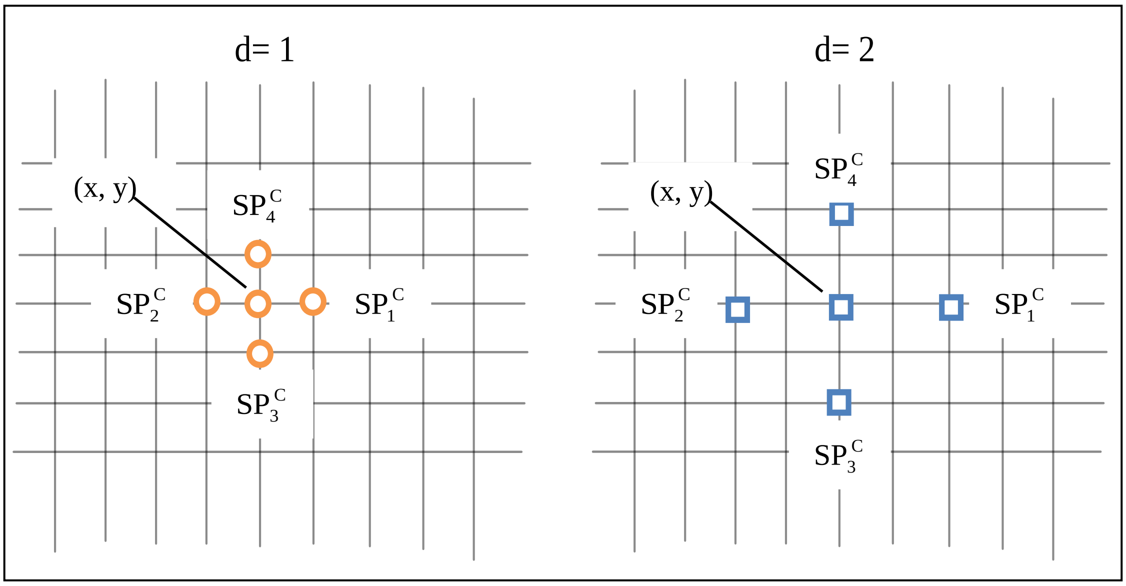

Figure 5.2: Cross Search

Let (x, y) be the initial search center point predicted for the cross search. The optimal search direction detection using the cross search is done using the four search points of the cross search pattern as shown in Equation (5.1).

$$\left.\begin{aligned}
SP_1^C &= (x+p, y) \; ; \quad p=0,\ldots,d \quad ; \; q=0,\ldots,d \\
SP_2^C &= (x-p, y) \; ; \quad p=0,\ldots,d \quad ; \; q=0,\ldots,d \\
SP_3^C &= (x, y-q) \; ; \quad p=0,\ldots,d \quad ; \; q=0,\ldots,d \\
SP_4^C &= (x, y+q) \; ; \quad p=0,\ldots,d \quad ; \; q=0,\ldots,d
\end{aligned}\right\} \tag{5.1}$$

The search for the direction is aligned with the center points along the horizontal right, horizontal left, vertical top and vertical bottom directions. The search points in the four directions are given by the Equation (5.1).

Where SP_1^C, SP_2^C, SP_3^C, and SP_4^C are the search points defined in the cross search region of $d \times d$. The varying cross search with the depth size of 1 and 2 representing the small cross search with 2×2 patterns and the large cross search with 4×4 patterns are shown in Figure 5.2.

ii. Square search:

The square search pattern is a center biased searching scheme [106]. The unique characteristic of the square search is the half way stop provision. The pattern size of the square search is fixed without depending on the search parameter values in the searching process.

Adaptive order square search:

In the AOCSH algorithm, the customary square search is modified with the adaptive order. The adaptive order chooses the size of the square search and the incorporation of the square search pattern in addition to the search algorithm present in the AOCSH algorithm is attained because of the order value. In motion estimation scheme, the square search pattern uses five searching points. They are four corner points and one center point. The direction of the motion movement waved up by the cross search is the origin of the square search. The ease of the square search is initiated by the cross search itself. The square search is done only in the concerned directions. The symmetrical searching capability of the square search allows it the quick detection of the motion in any direction. In the motion block, the motion movement is usually in the upward or the downward direction. If the vertical up is the direction guided by the cross search, the square search is done along the vertically up direction or vice versa.

So, the square search is beneficial and also robust. The order is the parameter introduced in the square search in the AOCSH search algorithm, to resemble the size of the square to search through. The order can be either 0 or 1. Depending upon the order value, the depth of the search value alters, arcing the size change of the square search pattern. The depth of the square search can be easily found using the following Equation (5.2),

$$d = O + C \tag{5.2}$$

Here, d is the depth or size of the square, O is the order of the search and C is the constant parameter. The nature of the order value is restricted to 0 and 1, so the square search in the AOCSH algorithm is of two sizes. The constant parameter C is fixed manually. Let (x, y) be the central location of the square search point. The searching of the best matching block containing the motion movement similar to that of the reference block is possibly done by following the four corner points, along with the guidance of the center point.

$$\left.\begin{array}{l} SP_1^S = (x+p, y+q) \;;\quad p = 0,\ldots,d \quad ; q = 0,\ldots,d \\ SP_2^S = (x-p, y+q) \;;\quad p = 0,\ldots,d \quad ; q = 0,\ldots,d \\ SP_3^S = (x+p, y-q) \;;\quad p = 0,\ldots,d \quad ; q = 0,\ldots,d \\ SP_4^S = (x-p, y-q) \;;\quad p = 0,\ldots,d \quad ; q = 0,\ldots,d \end{array}\right\}$$

The four search points are obtained by crossing the center search point with the corner points in the following directions; upper-right, upper-left, down-left and down-right respectively. It is given by above equation, where, SP_1^S, SP_2^S, SP_3^S and SP_4^S are the search points defined in the square region $d \times d$. For the order value 0 and the constant value 1, the depth value is given by,

$$d = O + C = 0 + 1 = 1.$$

Similarly, for the order value 1 and the constant value 1, the depth value is given by,

$$d = O + C = 1 + 1 = 2.$$

The variation in the depth value specifies the size change of the square search. In Figure 5.3, the square searches with the depth size of 1 and 2 for the motion estimation are viewed. The change in the size doesn't increase the number of search points in the square search.

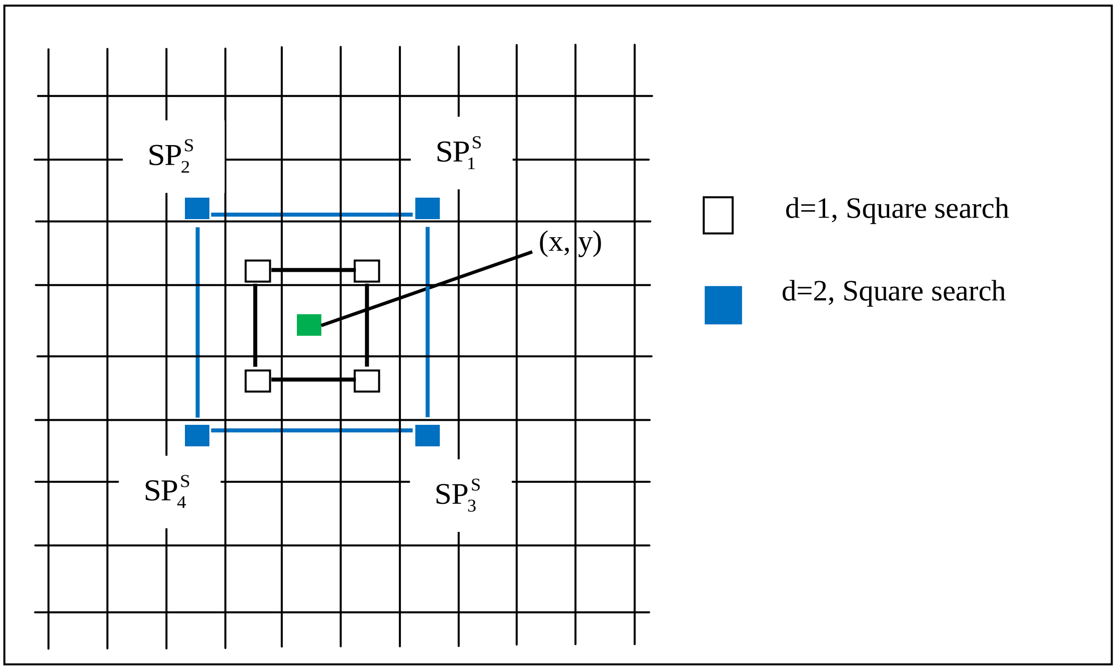

Figure 5.3: Adaptive Order Square Search

iii) Hexagonal search:

Hexagon search is of most vital considering the other search patterns used in the AOCSH algorithm. The motion due to the discontinuities such as translation, zooming, rotation and tilt motion in the macro blocks are found using the hexagonal search. Similar to the square search, the hexagon search is also a center biased one. The hexagonal search is the modified form of the diamond search [67]. The efficiency of the diamond search which is degraded considering the motion estimation perspective is increased in the hexagon search because of the additional two searching points present in it. Because of the hexagonal structure with fewer search points compared to the other search pattern, it has received the considerable development of the other block matching algorithms.

Adaptive order hexagon search:

The last search pattern used in the AOCSH algorithm is the hexagon search pattern. In the AOCSH algorithm, the hexagon search is also modified with the adaptive order. The discontinuities in the motion movement which are unable to detect using the square search can be easily detected using the hexagon search. The discontinuity motion detection is made easier in the hexagonal search pattern because of the definition of the search points in the hexagonal corner which is the wide area of the acceptance.

$$\left.\begin{aligned} SP_1^H &= (x+p, y+q) \;; \quad p=0,\ldots,d \quad ; q=0,\ldots,d \\ SP_2^H &= (x-p, y+q) \;; \quad p=0,\ldots,d \quad ; q=0,\ldots,d \\ SP_3^H &= (x+p, y-q) \;; \quad p=0,\ldots,d \quad ; q=0,\ldots,d \\ SP_4^H &= (x-p, y-q) \;; \quad p=0,\ldots,d \quad ; q=0,\ldots,d \\ SP_5^H &= (x-2*p, y) \;; \quad p=0,\ldots,d \quad ; q=0,\ldots,d \\ SP_6^H &= (x+2*p, y) \;; \quad p=0,\ldots,d \quad ; q=0,\ldots,d \end{aligned}\right\}$$

In hexagon search, seven search points from the pattern for the search. The search points contribute six corner points and one center point is shown in above equation. The depth of the hexagonal shape is described by the order value. The center point of the hexagon moves through the corner points to find the motion movement. Order parameter value for the hexagonal pattern is either 0 or 1. The depth of the pattern is defined as the summation of the order value and the constant value. Two sets of hexagons are introduced for finding the best matching block, because of the two order values considered. The constant value in the depth summation is fixed manually.

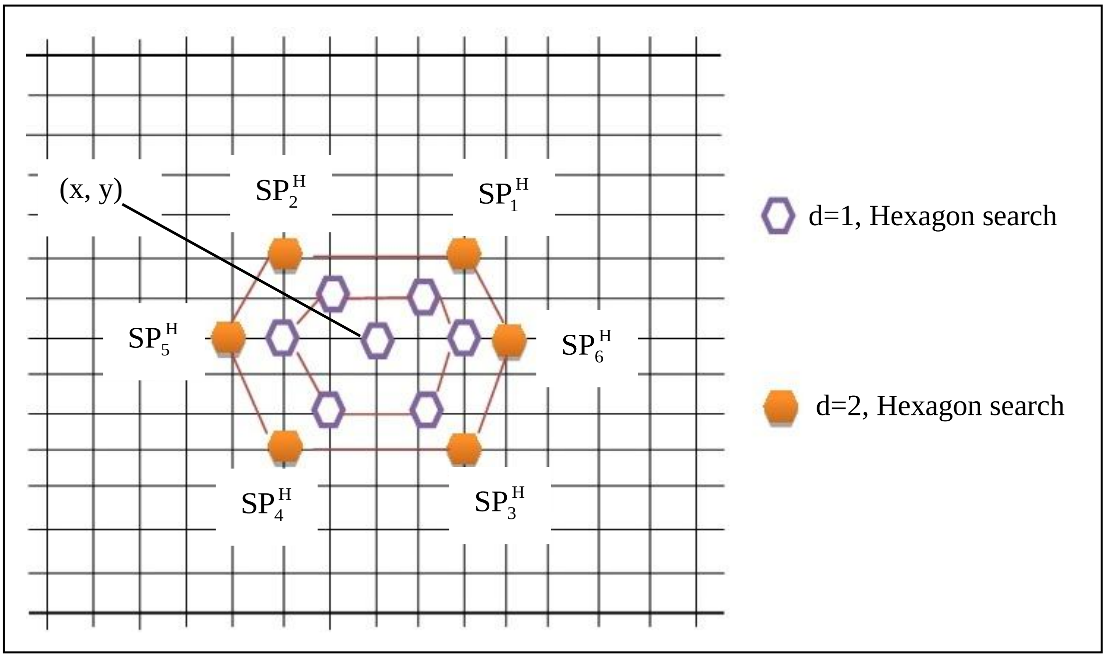

Figure 5.4: Adaptive Order Hexagon Search

Let us assume that (x, y) is the center location of the hexagon which represents the center search point. The center point is crossed alongside the direction of the six corner points for the detection of the matching points with the motion movement. The search points formed because of the traversal of the hexagon center search points on every possible direction of the corner points are given by above equation. Here, SP_1^H, SP_2^H, SP_3^H, SP_4^H, SP_5^H and SP_6^H are the six search points defined in the hexagon region $d \times d$. Figure 5.4 shows the adaptive order hexagon search. In Figure 5.4, the different depth sizes indicating the small and the larger hexagon search pattern is viewed. The size of the hexagon is changed only because of the order change.

5.2.2. Fuzzy tangent weighted trade-off criterion

In this section, the fuzzy tangent weighted trade-off criterion used for the evaluation of the matching points is discussed in this section. Trade-off function is the crucial step in the AOCSH motion estimation scheme. The center pixel of the image frame of the video sequence taken for the compression, moved through the cross shape, square shape and the hexagon shape search pattern induces the search point having the motion block. The selection criterion after searching different blocks using the search algorithm is based on the weighted function. The matching point evaluation is based on the weight of the block with the motion movement which is calculated based on the fuzzy tangent function.

The fuzzy tangent weighted trade-off function is evaluated based on the parameters rate and distortion. The advantage of the fuzzy function is utilized in the AOCSH trade-off function. Since fuzzy is the natural way to express the uncertain information, it helps in finding the optimal block among the uncertain motion movement in the macro blocks. The fuzzy function is more flexible and linear in parameter system by which the best possible block selection is made advantageous considering the normal tangent weighted function [113]. The fuzzy membership function converts the motion parameter of certain range into the linguistic variables. Thereby the possibility of selecting the best optimal matching block is improved because the restricted range selection is overcome by the linguistic variables. Based on the rate and distortion parameter, the maximization function is formulated as in Equation (5.3):

$$T(b) = \eta * T_d(b) + \tau * T_r(b) \tag{5.3}$$

Where, η is the weighted constant of the distortion parameter T_d and τ is the weighted constant of the rate parameter T_r. The rate parameter is designated to bring the best performance through the minimization of the storage bits needed while compression and the distortion parameters are designated to bring the best performance through the minimum motion block. In the maximization equation, the first parameter belonging to the distortion $T_d(b)$ depends on the motion dependent parameter $M(b)$ and the weighted function $W_d(b)$. The parameter regarding the distortion should be maximal for better performance. The distortion parameter $T_d(b)$ is given by Equation (5.4),

$$T_d(b) = f(M(b)) * W_d(b) \tag{5.4}$$

The function $f(M(b))$ is the fuzzy member ship function. The fuzzy function converts the motion dependent parameter into the linguistic function neglecting the restriction in the range. The fuzzy motion dependent parameter is calculated by a ratio of the size of the block with respect to the pixels having the static values. Equation (5.5) is the motion dependent parameter modified with the fuzzy function and is given as,

$$f(M(b)) = f\left(\frac{S(b) - A(b)}{S(b)}\right) \tag{5.5}$$

Where, $S(b)$ is the number of pixels in the block and $A(b)$ is the number of pixels having the dynamic values like the previous frame. The maximum value of $f(M(b))$ occurs only if the reference and the candidate blocks are equal. Equation (5.6) describes the weightage for the fuzzy motion dependent parameter and is given as,

$$W_d(b) = \left[\frac{1}{1 + exp[-S(b)]}\right] \tag{5.6}$$

The weighted function for $f(M(b))$ is based on the sizes of the block and the fuzzy tangent function which always lies on the linguistic variables. The second parameter in the trade-off maximization function is rate parameter $T_r(b)$. The rate parameter $T_r(b)$ depends on the rate-dependent parameter $R(b)$ and weighted function $W_r(b)$. The rate parameter $T_r(b)$ is given by Equation (5.7),

$$T_r(b) = f(R(b)) * W_r(b) \tag{5.7}$$

Where, $f(R(b))$ is the fuzzy member ship function of the rate-distortion parameter. The fuzzy function converts the range limited rate parameters to the linguistic variables. Equation (5.8) calculates the fuzzy rate dependent parameter.

$$f(R(b)) = f\left(\frac{R_B(b) - R_A(b)}{R_A(b)}\right) \tag{5.8}$$

Fuzzy rate dependent parameter is calculated by finding the difference ratio of the bits required to store the block before and after the CAVLC coding. The compression performance is better only if the value of $f(R(b))$ is maximal. Here, $R_A(b)$ is the number of bits required to store the block after the compression and $R_B(b)$ is the number of bits required for storing the block before compression. The weighted function for the rate dependent parameter $W_r(b)$ is calculated using Equation (5.9),

$$W_r(b) = \left[\frac{1}{1 + exp\left[-R_A(b)\right]}\right] \tag{5.9}$$

The weightage function $W_r(b)$ is based on the bits required for storing the block after the compression and fuzzy tangent function which always lies on the linguistic variables.

5.2.3. AOCSH algorithm

The AOCSH search algorithm and fuzzy tangent weighted trade-off function for the motion estimation scheme is discussed in this section.

Initially, the cross search pattern identifies the direction of the search, upon the direction estimated; the square search takes over for the motion estimation. Based on the depth of the search, the size of the pattern is selected which is based on the order value. For the order 1 and 0, two square sized patterns are utilized for searching of the motion block. After the square search, the hexagon search is adapted. Based on the order value, two hexagon sizes patterns are used for the motion search. The best search point with a maximal match to the reference frame is selected based on the fuzzy tangent weighted trade-off criterion.

Figure 5.5 shows the overall search procedure taking place in the AOCSH searching algorithm. In Figure 5.5, the direction identified using the cross search is the down ward direction. Upon the identified direction, the square and the hexagon search have their action.

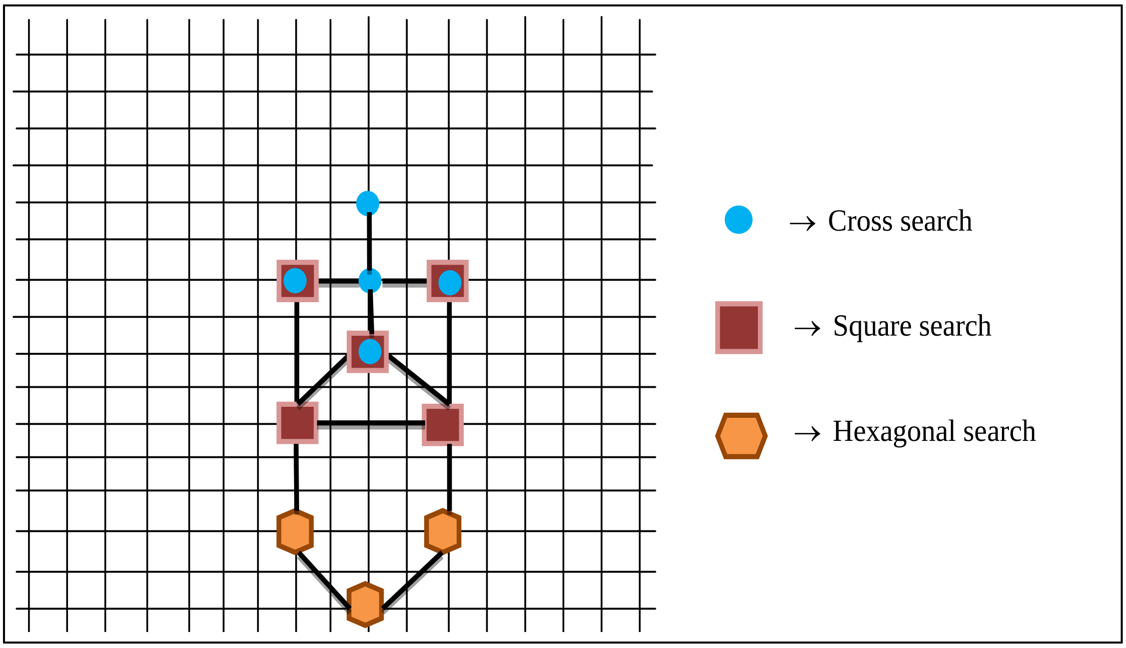

Figure 5.5: AOCSH Search Pattern

The flow of the AOCSH algorithm is described in five steps. The algorithmic description of the proposed motion estimation scheme is given below.

Step1: Starting. In the current frame, the center point (x, y) is located in the same location of the reference frame and a block of size $B \times B$ is formed by fixing the center point as center pixel.

Step 2: Cross search. The direction of the motion in the block is identified using the cross search and the discovered direction is initiated as the center for the successive steps of motion estimation.

Step 3: Adaptive order square search. The adaptive order square search is performed in the concerned direction specified by the cross search with order 0 and 1 of varying sizes by traversing through the four corner points in every possible direction. The search points with a maximal match to the reference block having the motion movements are selected.

Step 4: Adaptive order hexagon search. Similarly, adaptive order hexagon search is performed with order 0 and 1 of varying sizes by traversing through the six corner points in every possible direction. The search points with the maximal match to the reference block having the motion movements are selected.

Step 5: Fuzzy tangent weighted trade-off based selection. For the entire pixel visited through the hexagon and square search, the best block is evaluated based on the fuzzy tangent weighted trade-off function. The block having the maximal trade-off function is selected as the best matching block.

AOCSH algorithm:

Input: Initial Point, (x, y) constant, C

Output: Best matching point (x_a, y_b)

Procedure:

Start

Read initial point, (x, y)

Draw block for the initial point

Find the trade-off criterion, $T(b)$

Directional cross search

Get search points SP_1^C, SP_2^C, SP_3^C, and SP_4^C using cross search

Initiate directional search points as the center points

For order 0 and 1

Find depth d

Get search points SP_1^S, SP_2^S, SP_3^S, and SP_4^S using square search

Get search points SP_1^H, SP_2^H, SP_3^H, SP_4^H, SP_5^H, and SP_6^H using hexagon search

Find the trade-off criterion, $T(b)$ for all the search points

End for

Select the best point (x_a, y_b)

Return the best point (x_a, y_b)

5.2.4. Encoding with the AOCSH algorithm

The encoding issues related to the AOCSH algorithm is discussed in this section. The motion vectors are generated for the best matching blocks selected by the trade-off function. Subsequently, after the motion vectors, bits stream generation is the objective of the video compression. The encoding process is almost similar to that of the H.264/AVC video compression standard. Primarily, the height of the frame, width of the frame, number of frames, frame rate and scalable quantization parameters are encoded as 8 or 16 bits. Once the parameters associated with image frames are encoded, Inter frame is encoded by CAVLC coding. Before entropy coding, I frame is subjected to blocking, integer transformation, and quantization and encoded into bits. Every predicted frame is encoded based on the motion vectors and mode. A mode is used to recognize the location of the search points as they are encoded in three bits. The first bit denotes the order of the search; second bit and third bit denote the direction of the motion movement. Second bit denotes the direction either in upward or downwards. The third bit denotes the direction of the movement in the right or the left direction. The bit coding out of the CAVLC is inserted for the transmission only after the mode is inserted. This process is continued for the entire frame in the video sequence.

5.3 SUMMARY

In this chapter, an adaptive order cross square hexagonal search algorithm and fuzzy tangent weighted 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 searches 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 and the elastic method. The performance evaluation was done using the performance metrics; structural similarity index and peak signal to noise ratio. The AOCSH and fuzzy 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. The simulation results of AOCSH search algorithm and fuzzy tangent weighted trade-off based video compression method are discussed in chapter 6.