CHAPTER 5

DESIGN OF VIDEO WATERMARKING TECHNIQUES

Watermarking algorithm consists of two main steps, namely, embedding and extraction of watermarks into the cover video. Both these steps have to be designed carefully, as that hacking or illegal copying of video content is made difficult. In general, a watermark can be inserted into a video in three ways,

(i) in the uncompressed domain or

(ii) during the compression process or

(iii) after the compression process.

Watermarking during the compression process requires an implementation of the watermarking framework to the encoder. Watermarking after the compression process limits the embedding process to the current compression standard. Embedding the watermark in the uncompressed domain has the advantage that the video data can be compressed with different standards and data rates. However, the embedded watermark has to be robust to the compression. The second and third phases of the research work focuses on the design and development of watermarking techniques for uncompressed and compressed videos (MPEG video format).

5.1. GENERATION OF WATERMARK

In order to increase the payload of the proposed algorithm a nested watermark where one watermark is embedded into another is used. The procedure consists of the following three steps.

(i) Generate a binary watermark

(ii) Prepare Copyright image and

(iii) Insert binary image into copyright image

The process of generating binary watermark is presented below.

- Generate a binary image W as watermark of copyright protection.
- For each pixel of W, the gray value of W(i, j) equals to either 1 or 0.
- Generate a new non-zero watermark sequence $W^d(i, j)$, and is calculated using Equation (5.1)

$$W^{d}(i,j) = \begin{cases} 1 & \text{if } W(i,j)=1 \\ -1 & \text{if } W(i,j)=0 \end{cases} \tag{5.1}$$

The procedure for creating the nested watermark, with the binary image (created using the above procedure) and the copyright image consists of the following steps.

- Perform Visual Cryptography on the copyright image to obtain Share 1 and Share 2.
- Read Share 1
- Perform 2D DWT on Share 1 to obtain LL, LH, HL and HH subbands.
- Read Binary image
- Add Binary image in LL subband
- Perform IDWT to get nested watermark.

A reverse process is used to obtain the copyright image and binary image.

5.2. WATERMARKING IN UNCOMPRESSED VIDEO

The watermarking algorithms proposed for uncompressed domain have various features that make it different from existing algorithms. The first is that the embedding procedure used is block-based. Most of the existing watermarking schemes are non-block-based schemes, which mean that the same technique is used in all frame parts ignoring that each part of the image may have its own characteristics, such as dark areas, texture areas, etc. To increase the capacity of information and to resist attacks, static or dynamic blocking of frames along with transformation is used.

Static block-based watermarking techniques consist of dividing the frmae into non-overlapping blocks of pixels and inserting a mark into each block. Dynamic block-based techniques use dynamic methods to create these blocks.

The second feature of proposed algorithm is that the embedding is performed on the relevant border portion of the video data. It is always desirable to have the watermark to be perceptually invisible. Existing solutions embed watermark in the irrelevant and perceptually invisible parts of the video (Figure 5.1). It is a well-known fact that insertion of watermark cause distortion in the cover video. All the techniques attempt to reduce this induced distortion caused by the watermark. For this purpose, to measure distortion Peak Signal to Noise Ratio (PSNR) measure is generally used.

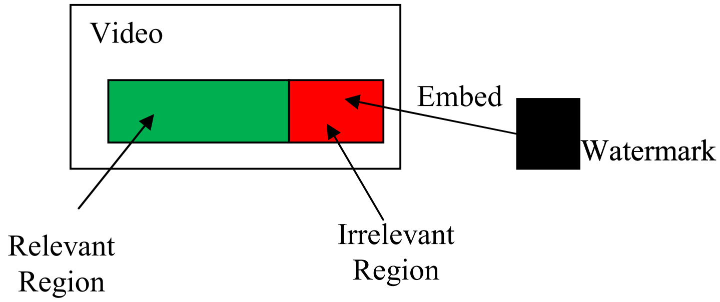


Figure 5.1 : Watermark Embedding in Irrelevant Region of Video

Compression of a video consists of two steps. First step tries to remove irrelevant information (red coloured region in Figure 5.1), while second step reduces the redundancy of the data. This scenario is presented in Figure 5.2.

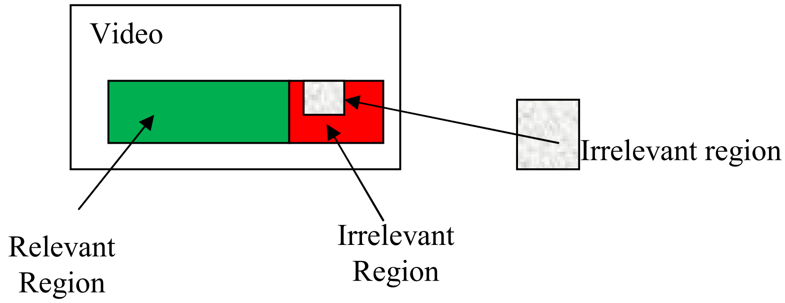


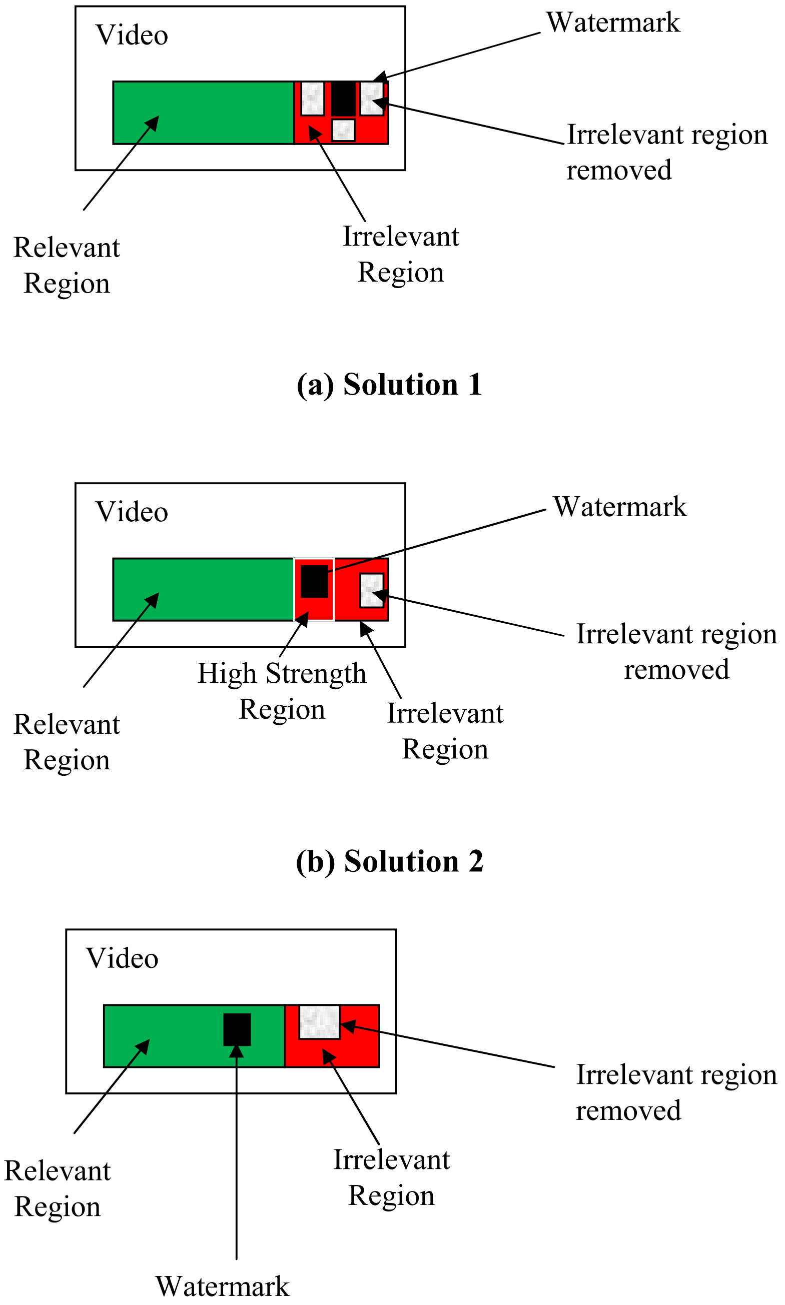
Figure 5.2 : Compression Technique Removes Irrelevant Region of Video

Both embedding of watermark and means to achieve compression is centered on the irrelevant region. Thus, while embedding watermark in video, care should be taken so that the compression algorithm does not remove the watermark while removing the irrelevant region. To solve this contradiction, three solutions exist.

The first solution attempts to find gaps in the irrelevant regions not used by the compression algorithm. At present, no compression algorithm is perfect. Hence, the algorithm does not remove all perceptual invisible parts of video information. By finding this gap, the watermark could be embedded in the residual perceptual invisible parts (Figure 5.3a). A disadvantage of this solution is, especially with new high efficiency compression algorithms, it is difficult to find such gaps. A second disadvantage is the lack of universal watermark approach. The watermark is only robust to the specific compression algorithm.

The second solution is to embed the watermark with a defined strength. Hence, the watermark embedding degrades the video quality as less as possible and achieves robustness to the lossy video compression (Figure 5.3b) However, as the compression ratio is unknown, the watermark has to be embedded from high strength regions to low strength regions, in order to be robust and to achieve high compression ratios.

The third solution is to embed the watermark in the relevant and visible part of the video in an imperceptible manner (Figure 5.3c). The advantage of this approach is high robustness against compression attacks. This solution is used in the design of watermarking algorithms for uncompressed domain.



(a) Solution 1

(b) Solution 2

(c) Solution 3

Figure 5.3 : Solutions to Contradiction Problem

In order to realize visible-imperceptible region and according to PSNR definition, object borders are definitely visible and are relatively untouched by compression algorithms, as a change in border position results in heavy degradation of PSNR values. This scenario is presented in Figure 5.4, which shows a frame with two objects having different gray levels. As a live example, consider the frame in Figure 5.5 (Foreman video compressed using MPEG format). From the figure, it can be seen that the spatial position of the window object is relatively unchanged. By quantizing the values of the x,y-coordinates of the window position, only by few pixels, the watermark can be embedded. This watermark is robust to lossy compression and comparison of PSNR of the whole video shows minimal distortion.

Object-borders achieve a high robustness to lossy compression. This can be used for watermarking but it is a non trivial problem. During watermark recovery, consider for example, if some objects are chosen for embedding whose spatial position is changed slightly. This method of embedding watermarks is called using Geometric Warping method (Pröfrock *et al.*, 2006).

In order to recover the watermark, the exact same objects have to be found, even though the video has been changed by compression. This problem is solved through the use a block-based watermarking approach and describes only object borders inside single blocks. Now, it can be decided for each block, whether to use one block for embedding a watermark bit or not. For this purpose Normed Centre of Gravity (NCG) method is used.

The third feature exploits the characteristics of the HVS in wavelet packet coefficients to effectively find the frame edge information that can be removed without degrading the subjective quality of the visual perception. For this the Just Noticeable Difference (JND) criterion is used.

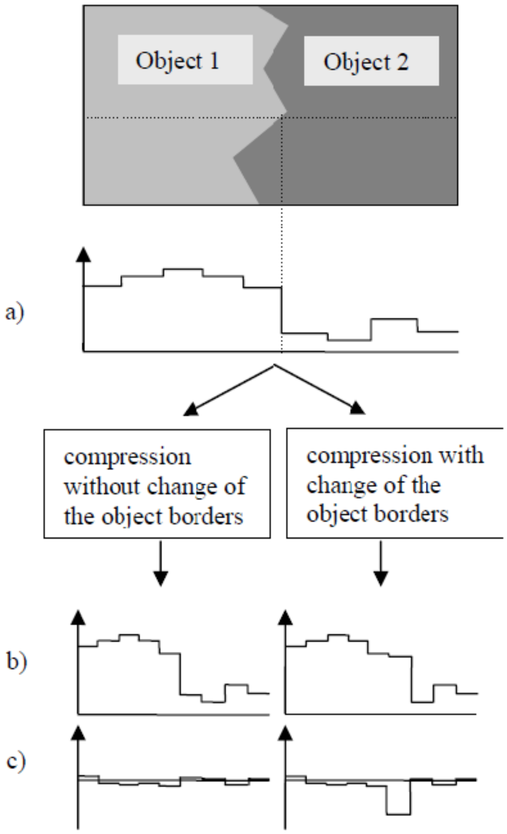

Object 1
Object 2
a)
compression without change of the object borders
compression with change of the object borders
b)
c)

Figure 5.4 : Compression of Object Borders

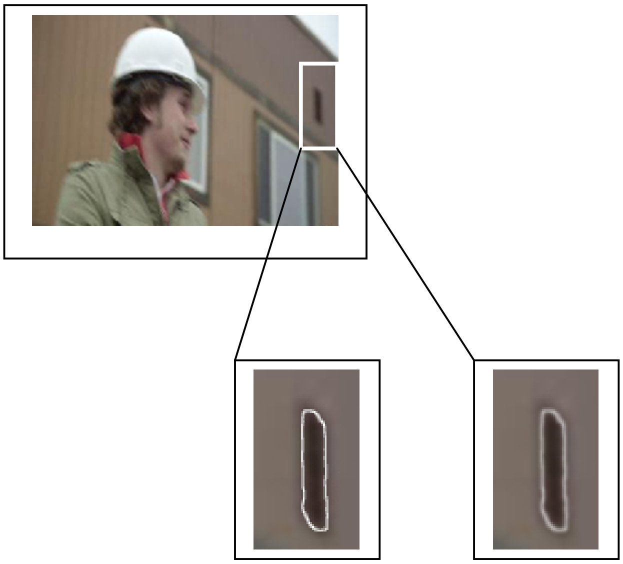


Figure 5.5 : Spatial Position of Window

The fourth feature is the usage of Artificial Neural Network (ANN) to memorize the relationships between the original wavelet coefficients and its watermark version. The trained ANN is utilized for estimating the watermark without the original Frame. This brings the advantage of avoiding the need for the original video frames to be available during watermark extraction.

Thus, combining the various features with wavelet packets, Phase II of the study proposes two algorithms namely,

(i) Enhanced Wavelet Packet-based watermarking algorithm based on Geometric Warping with HVS based criteria using neural network combined with Static Blocking Algorithm (WGSBS Algorithm).

(ii) Enhanced Wavelet Packet-based watermarking algorithm based on Geometric Warping with HVS based criteria using neural network combined with dynamic Blocking Algorithm (WGDBS Algorithm).

5.2.1. WGSBS Algorithm

The steps in the WGSBS proposed model are shown in Figure 5.6. The algorithm using the frames and regions selected in Phase I first performs DWPT to obtain subbands which are then segmented into non-overlapping 8 x 8 blocks. The Just Noticeable Difference HVS characteristics are then calculated to obtain the allowable visibility ranges for all coefficients of a wavelet-packet transformed image. The inclusion of JND increases the imperceptibility of the algorithm. An Artificial Neural Network (ANN) is then used to memorize the relationships between the original wavelet coefficients and its watermark version. A geometric warping method is then used to embed the watermark in the selected regions of the frames. After which an inverse DWPT is performed to obtain the watermarked image. The geometric warping method is enhanced through the use a block selection algorithm. The block selection algorithm aims to reduce the artifacts or flickering effects introduced by the original warping method. The methods used in the various steps of the proposed model are presented in the following subsections.

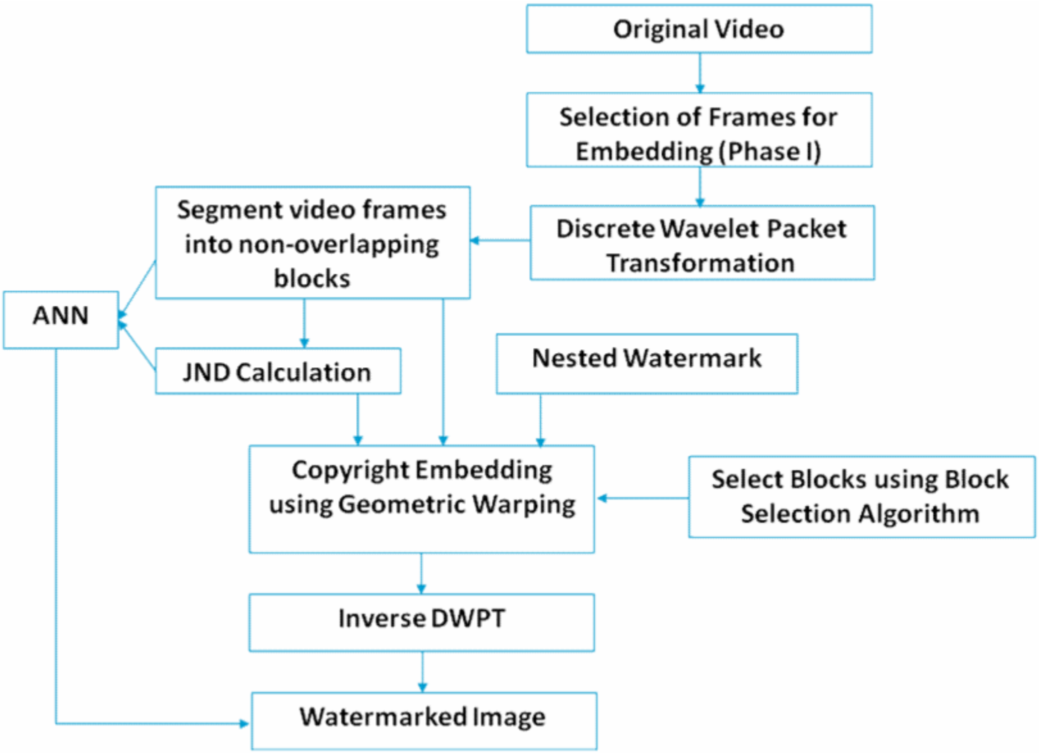

Original Video
Selection of Frames for Embedding (Phase I)
Discrete Wavelet Packet Transformation
Segment video frames into non-overlapping blocks
ANN
JND Calculation
Nested Watermark
Copyright Embedding using Geometric Warping
Select Blocks using Block Selection Algorithm
Inverse DWPT
Watermarked Image

Figure 5.6 : WGSBS Embedding Algorithm

5.2.2. WGDBS Algorithm

The steps in the WGDBS proposed model are shown in Figure 5.7. The steps in WGDBS algorithm vary only in the formation of non-overlapping blocks where a clustering algorithm is used to group the pixels into different groups. For this purpose, a spatial and feature based clustering is used. The method is devised to group pixel data by taking into account simultaneously both their feature space similarity and spatial coherence.

The various techniques used in both WGSBS and WGDBS are described in the following subsections.

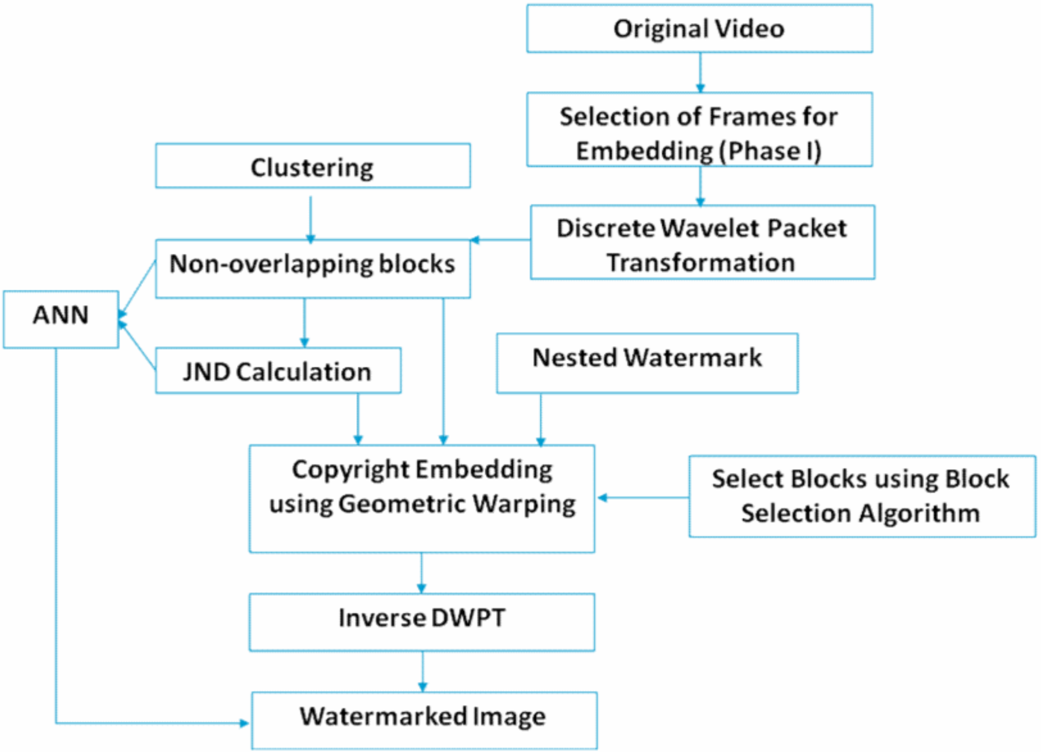

Original Video
Selection of Frames for Embedding (Phase I)
Clustering
Discrete Wavelet Packet Transformation
Non-overlapping blocks
ANN
JND Calculation
Nested Watermark
Copyright Embedding using Geometric Warping
Select Blocks using Block Selection Algorithm
Inverse DWPT
Watermarked Image

Figure 5.7 : WGDBS Embedding Algorithm

- **Static Block Creation**

Static blocks are created by dividing the video frame into fixed sized, non-overlapping blocks of size 16 x 16. This method of creating blocks is used by WGSBS algorithm only.

- **Dynamic Block Creation**

The dynamic blocks are created using a clustering approach proposed by Matas and Killer (1995). The method exploits both spatial and feature space using Graph Theoretic (GT) clustering algorithm Koontz *et al.* (1976), which is a basic building block combined with Feature and Spatial Domain (FSD) clustering method. The algorithm is given in Figure 5.8. Each cluster obtained from the algorithm is treated as a block that can be used for embedding the watermark.

Step 1 : Perform graph-theoretical clustering.

1. Compute feature histogram. In each bin, maintain a list of pixels voting for the bin.
2. For each bin, find the bin with maximal count in a given neighbourhood. Store a link to this bin.
3. Such links form a forest, with a root of each tree in a local maximum. The set of pixels voting for bins in a single tree form a unimodal cluster.

Step 2 : Terminate if:

1. No local maximum exists.
2. Global maximum is bellow a threshold or the required number of regions is found else select the current global maximum.

Step 3 : Traverse the tree rooted at current maximum to obtain a list of bins that belong to a unimodal cluster

Step 4 : Check local (ie. connected component) consistency.

1. Back project all pixels voting into bins of the unimodal cluster in the image. Perform connected component analysis.
2. Sort the list of connected components by size.
3. Histogram computed on the largest connected component forms the initial model of the cluster distribution (in feature space).
4. Iterating through the sorted list, statistically test whether the current model of cluster distribution is consistent with the distribution computed on the next connected component. Votes from accepted components are removed from the global histogram.

Step 5 : Iteratively add pixels that are *both* in spatial and feature space neighbourhoods of the cluster.

Step 6 : Update the list of local maxima and go to step 2

Figure 5.8 : Clustering Algorithm for Dynamic Block Creation

- **The NCG Algorithm**

The NCG algorithm (Pröfrock *et al.*, 2006, 2007) consists of the steps given below and the process is shown in Figure 5.9.

1. Compute the mean values of the rows and columns of the block and store it in M_x and M_y.
2. Using M_x and M_y, compute x- and y-coordinate of the NCG. (This arranges the two vectors in two circles).
3. Compute the 2-D vector v_k (k=x or y) using Equation (5.2)

$$v_k = \begin{pmatrix} \sum_{i=1}^{n} m_k(i).\cos\left(\frac{\pi}{n} + \left((i-1).\left(\frac{2\pi}{n}\right)\right)\right) \\ \sum_{i=1}^{n} m_k(i).\sin\left(\frac{\pi}{n} + \left((i-1).\left(\frac{2\pi}{n}\right)\right)\right) \end{pmatrix} \qquad (5.2)$$

4. For each vector, compute the vector angles (Equation 5.3) and the vector lengths Lx, Ly.

$$k = \frac{n\theta_k}{2\pi} \quad \text{for } (k = x \text{ or } y) \qquad (5.3)$$

Where θ is the angle, n is the block width.

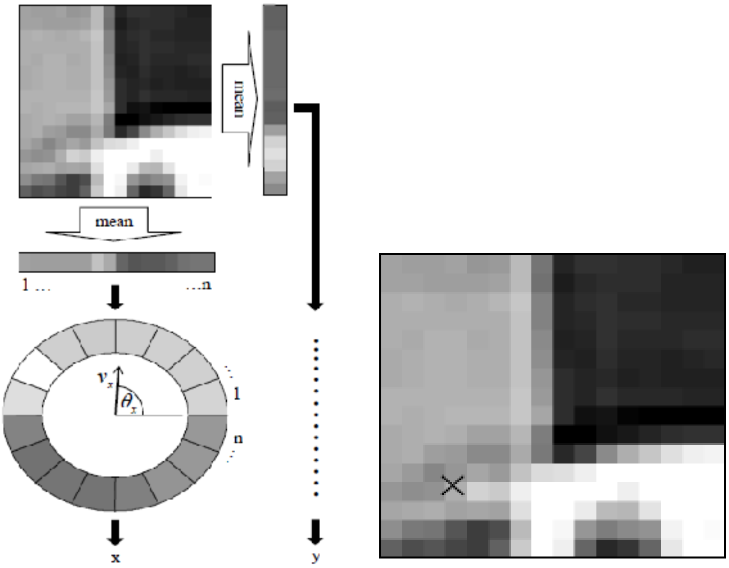


Figure 5.9 : NCG Process

The main advantage of NCG is that it is robust against any compression algorithms. The NCG of blocks with distinct object borders are robust to compression algorithms while NCG blocks without distinct object borders are not robust. Distinct object borders result in high vector lengths, using which the robustness of the NCG x,y-coordinates can be predicted. The NCG x,y- coordinates distortion decreases with increase in vector length. Through experiments, it was proved that the distortion for vector lengths greater than 430 is lower than 0.25 pixels for compression rates upto QP (Quantization Parameter) less than equal to 40. Hence, a watermark can be embedded by quantizing the values of the x,y-coordinates of blocks using a quantization step size of one. This watermark will be robust to compression rates upto QP less than equal to 40.

During embedding of watermark, the first step is to find the vector length L_{min} which ensures the required robustness. After which, the blocks with $L > L_{min}$ are chosen. To embed an watermark bit, the values of the x,y- coordinates of the NCG are quantized. The quantization is done by geometric warping of the block. The direction and strength of warping depends on the original and the quantized NCG-coordinates. To prevent block artifacts to neighbor blocks, the warping process uses different weights for the strength of warping the single pixels. The weight is computed using a quadratic function (Figure 5.10). This geometric warping process is used to change the NCG x,y- coordinates.

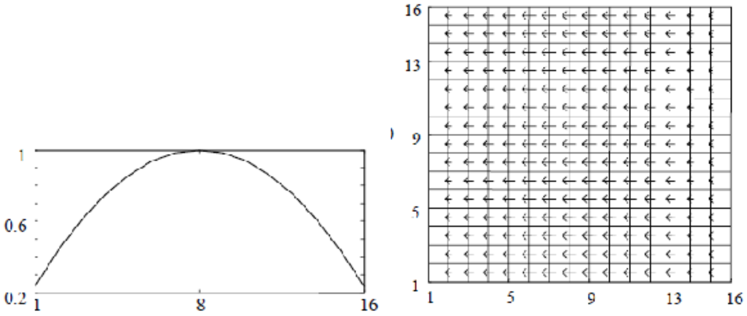


Figure 5.10 : Weighting Function and Example for Geometric Warping

- **Block Selection Procedure**

To avoid blocking artifacts the geometric warping method uses a block selection procedure. In block selection technique, the selected blocks should maintain minimum distance d to each other in order to prevent artifacts and flickering effects. The minimum distance can be calculated using Equation (5.4).

$$[d_i = \lfloor \log(d.(i_{size} - 1) + 1) + 0,.5 \rfloor \qquad (5.4)$$

where d is the distance and i is the dimensions (x, y or t). The steps involved in the block selection algorithm used are given in below.

- Step 1 : Select a block group which is of arbitrary forms.
- Step 2 : The minimum distance dx, dy and dt is computed for each dimension x, y and t of the block group.
- Step 3 : The numbers of blocks inside an ellipsoid are counted for each block. The semi-axes of the ellipsoids are defined by dx, dy and dt. The current block defines the center of the current ellipsoid.
- Step 4 : The blocks with the least neighbors are chosen for watermarking. If more than one chosen blocks inside an ellipsoid, only one of them (the first) is used for watermarking.
- Step 5 : The chosen blocks and all blocks within the ellipsoids around the chosen blocks will not be considered in the next steps.
- Step 6 : The steps 3-4 are repeated until all blocks are chosen for watermarking or have a distance lower than the minimum to a chosen block.

- **The JND Criterion**

JND is defined as the smallest detectable difference between two blocks of a frame. The JND models used in this work tends to exploit three basic types of phenomena, namely,

- Non-uniform frequency response of human eye (contrast sensitivity - t_{CSF})
- Sensitivity to the different brightness levels (luminance masking) - t_L
- Sensitivity to one frequency component in the presence of another (contrast or texture masking - T_c).

$$t_{JND}(b1,b2,i, j) = t_{CSF}(i, j) \text{ x } t_L(n1,n2,i, j) \text{ x } t_c(n1,n2,i, j)$$

where b1 and b2 are blocks of video frame, i and j refer to the position of the DWPT coefficients

The resultant product would be a frame, exactly, or almost exactly, like the original image, but with a watermark embedded within that the naked eye will not be able to see.

- **Artificial Neural Network**

The ANN architecture used during the study is given in Figure 5.11 (and consists of three layers: the input layer with 16 neurons, the hidden layer with 12 neurons, and the output layer with a single neuron (Haykin, 1999). The ANN is called a 16-12-1 MultiLayer Perceptrons (MLP). A back propagation learning algorithm is applied to train the ANN by correcting its weights. These weights are adjusted to decrease the errors between the inputs and their corresponding target outputs (Tsai and Liu, 2011).

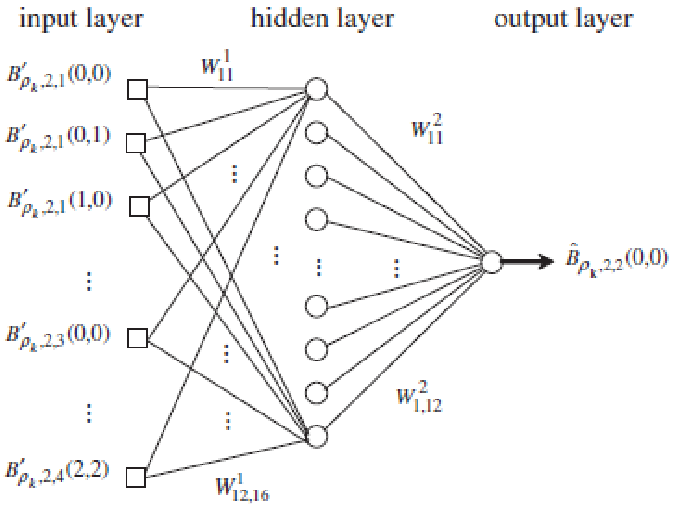


Figure 5.11 : Architecture of ANN

Let W^{1}_{ji} denote a weight connecting the ith neuron in layer l to the j_{th} neuron inlayer *l*-1. Accordingly, a set, γ, of weights in the ANN can be denoted as

$$\gamma = \left\{W^1_{ij} \mid i = 1,2,...,12, j = 1,2,...16\right\} \cup \left\{W^2_{ij} \mid i = 1, j = 1,2,...16\right\} \qquad (5.5)$$

$\hat{B}_{\rho_k,2,2}(0,0)$ represents a physical output of the ANN. A set, Θ, of training patterns can be gathered from Ψ and its watermarked version and can be expressed as a form

$$\Xi = \left\{(B'_{\rho k}, B_{\rho_k,2,2}(0,0)) \mid K = 1,2,...,m\right\} \qquad (5.6)$$

where $B'_{\rho k}$ denotes the input vector of the kth training pattern in Θ, and which is specified as

$$B'_{\rho_k} = (B'_{\rho_k,2,1}(0,0),...,B'_{\rho_k,2,2}(0,0),...,B'_{\rho_k,2,4}(0,0),...,B'_{\rho_k,2,4}(1,1)$$

$$(5.7)$$

In addition, $B_{\rho_k,2,2}(0,0)$ stands for the desired output of the kth training pattern.

5.2.3. Watermark Extraction Process

The procedure for extracting the watermark is given in Figure 5.12.

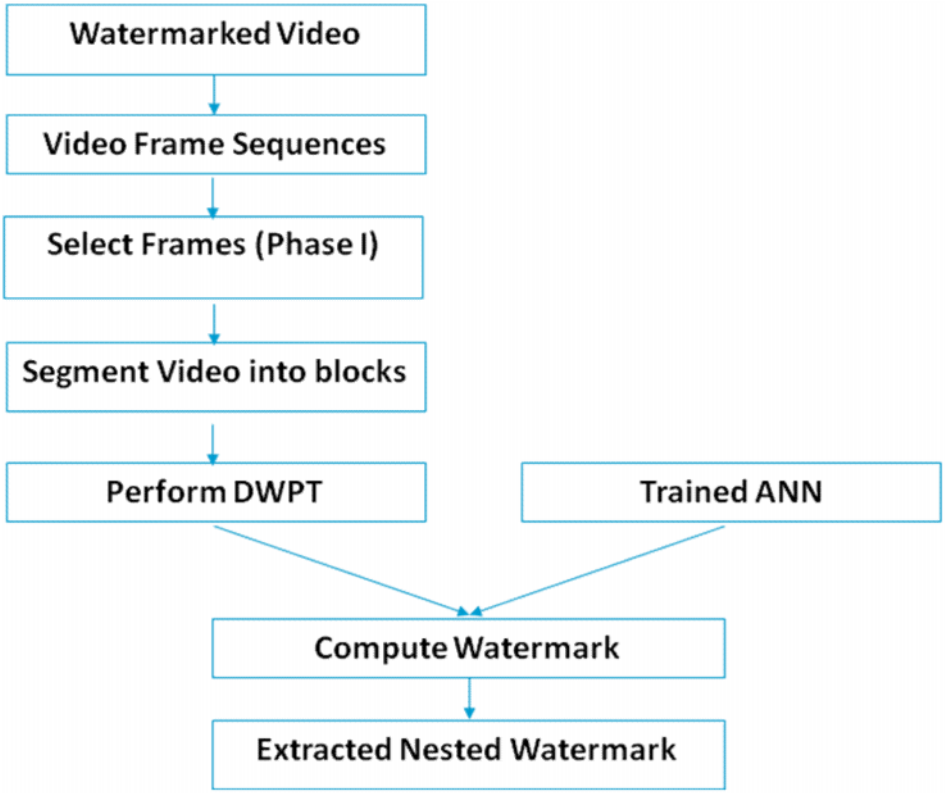


Figure 5.12 : Watermark Extraction Process

The extraction algorithm first selects the frames where the watermark is embedded, performs static or dynamic block selection and then performs DWPT to receive coefficients. These coefficients along with the trained ANN are then used to compute and extract the nested watermark. To extract the watermark bits, the blocks with $L > L_{min}$ are chosen. From the NCG coordinates of the chosen blocks the embedded bit values can be computed. Thus, to extract the watermark, the original video is not needed. The NCG is used to detect the watermarked blocks and compute the embedded watermark bit. After successful extraction of the watermarked bits, the next step is to extract the nested watermark. From the nested watermark, the copyright image is obtained using the procedure given in Figure 5.13.

- Apply 2D-DWT to obtain LL, LH, HL and HH subbands
- Extract and Remove Share2 from LL subband
- Extract binary image
- Perform IDWT to obtain Share 1
- XOR share 1 and share 2 to obtain copyright image

Figure 5.13 : Nested Watermark Extraction Procedure

5.3. WATERMARKING IN COMPRESSED VIDEO

Phase III of the study focuses on developing watermarking algorithms for compressed video data. For this purpose, two approaches are enhanced, namely, transformation-based algorithm and feature point-based algorithm. Under transformation-based, two techniques namely, Discrete Cosine Transformation and Discrete Wavelet Packet Transformation are considered. In order to increase the robustness the method is combined with clustering and Singular Value Decomposition (SVD). In feature point based algorithm, the Harris-Laplacian Feature Point Detection algorithm is used. Thus the third phase of the research work proposes three algorithms as listed below.

(i) DCT-SVD combined with Clustering Algorithm (DCT-SVD)

(ii) DWPT-SVD combined with Clustering Algorithm (DWPT-SVD)

(iii) Harris-Laplacian Feature Point Based Algorithm (FPBA)

5.3.1. DCT-SVD and DWPT-SVD Algorithm

This section presents the algorithmic details of DCT-SVD and DWPT-SVD algorithms. As SVD is the main component of both the algorithms, a description of the same is first provided, followed by the description of the proposed algorithms.

- **Singular Value Decomposition (SVD)**

The singular value decomposition (Demmel, 1997; Berry *et al.*, 1999) is a more general method that factors any m x n matrix A of rank r into a product of three matrices, such that

$$A = U \sum V^T \qquad (5.8)$$

where U is m x m (left singular vectors), $\sum$ is m x n and V is n x n (right singular vectors). U and V are both orthonormal matrices (i.e., $UU^T = I_m$ and $VV^T = I_n$) and $\sum$ is an m x n matrix where the non-negative and descendingly ordered elements along the diagonal of the left / top quadratic subblock are the singular value $\sigma_1 \geq \sigma_2 \geq \sigma_3 \ldots \geq \sigma_r \geq 0$ of A. All other elements of $\sum$ are 0.

If r < min(m, n), that is, the matrix A is not full-rank, then only r singular values are greater than 0. A full rank decomposition of A is usually denoted as $A_r = U_r$ Erode V_r^T. The singular values are always real numbers. If the matrix A is real, then U and V are also real. The relative sizes of the matrices U, $\sum$ and V are shown in Figure 5.14. All entries not explicitly indicated in $\sum$ are zero.

The reduced rank SVD to A can be found by setting all but the first k largest singular values equal to zero and using only the first k columns of U and V. This is denoted using Equation 5.9.

$$A_k=U_k \sum_k V_k^T \qquad (5.9)$$

A theorem by Eckart and Young (1936) states that amongst all possible rank k approximations, A_k is the best approximation in the sense that $||A-A_k||_F$ is as small as possible, in other words, the singular value decomposition gives the closest rank k approximation of a matrix, such that

$$||A-A_k||_F \leq ||A-B_k||_F \qquad (5.10)$$

where B_k is any matrix of rank k and $||.||_F$ is the Frobenius norm, which is defined as $(\Sigma\ |a_{ij}|^2)^{1/2} = ||A||_F)$. Since both, pre-multiplying an m x n matrix X with an m x m orthogonal matrix and post multiplying X with an n x n orthogonal matrix leaves the Frobenius norm unchanged, it can be shown that the Frobenium norm of A is equal to the Euclidean norm of the vector containing all singular values

$$||A||_F = ||U\ \Sigma V^T||_F = ||\Sigma V^T||_F = ||\Sigma||_F = \sqrt{\sum_{j=1}^{r_A} \sigma_j^2} \tag{5.11}$$

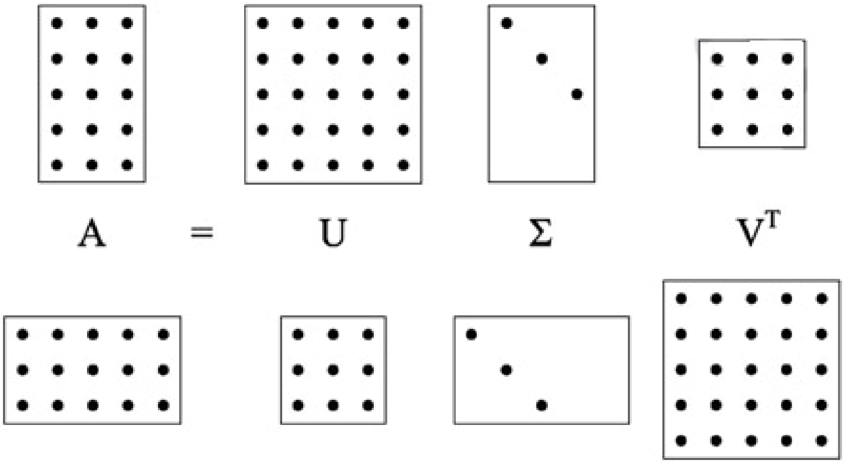


Figure 5.14 : Illustration of SVD
(Source : Berry, 1999)

- **Proposed Transformation Based Algorithms**

During embedding, the dynamic block selection algorithm discussed previously is used. Either a Discrete Cosine Transformation or DWPT transformation is performed to obtain coefficients. The next step applies SVD on these coefficients to obtain SVD values. The watermark is embedded in the U component to increase robustness. Finally inverse SVD followed by IDCT or IDWPT is performed to obtain the watermarked frame. The steps of DCT-SVD and DWPT-SVD algorithms are shown in Figure 5.15.

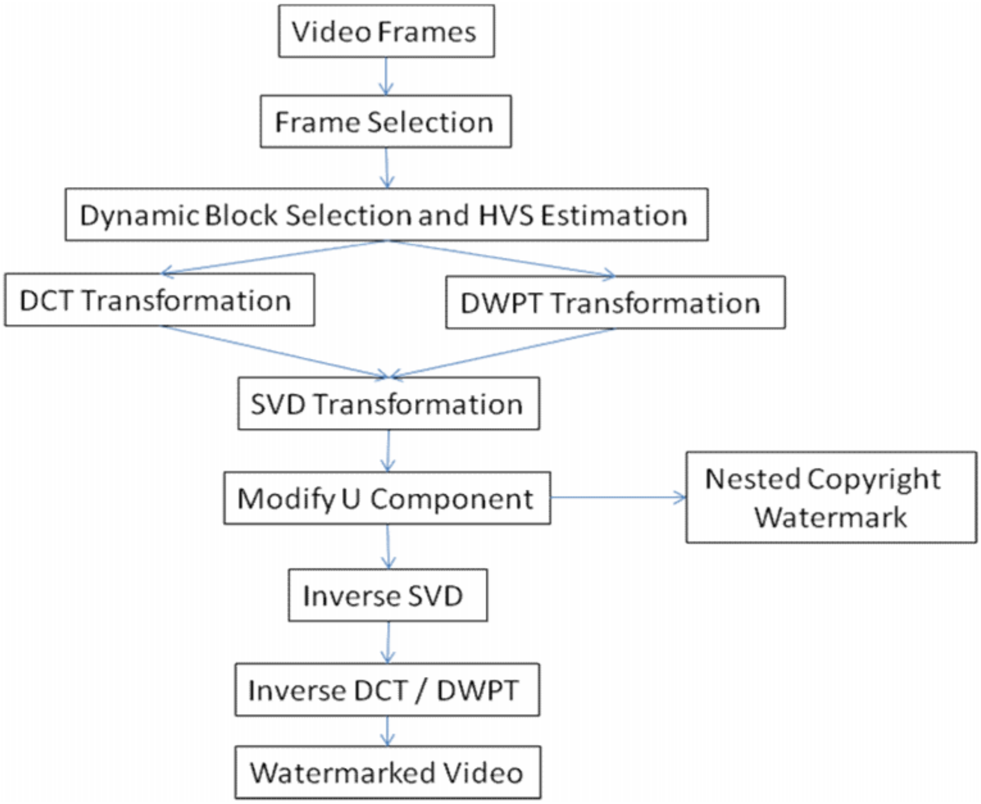


Figure 5.15 : DCT-SVD and DWPT-SVD Algorithms

The SVD technique provides an elegant way for extracting algebraic features from an image. One of the features is that the relationship between the entries in the first column vector of the U component could be preserved, while for other columns the entries are changed when general image processing was performed. The usage of SVD technique provides an elegant way for extracting algebraic features from a frame. According to Faragallah (2013), while using SVD, the visual degradation of video data can be minimized if the relationship between the entries in the first column vector of the U component is preserved, while changing the entries in the other columns. The research also utilizes this property and uses the singular values apart from the first column vector of the U component to insert the watermark. The SVD-U component modification procedure is presented in Figure 5.16.

- On each selected block, the relationship between the entries in the first column of the U matrix is examined.
- The watermark is embedded by changing the relation between the third ($u_{3,1}$) and the fourth ($u_{4,1}$) entries in the first column.
- If the embedded binary watermark bit is 1, then the value of ($u_{3,1} - u_{4,1}$) should be positive and its magnitude is greater than a threshold (T).
- If the embedded binary watermark bit is 0, then the value of ($u_{3,1} - u_{4,1}$) should be negative and its magnitude is greater than a threshold (T).
- When these two conditions are violated, the entries of $u_{3,1}$ and $u_{4,1}$ should be modified as $u'_{3,1}$ and $u'_{4,1}$, respectively based on the following rules

  Let $\mu = (|U_{3,1}| + |U_{4,1}|)/2$.

  $$\text{if } w_k = 1, \begin{cases} u'_{3,1} = \mu + T/2 \\ u'_{4,1} = \mu - T/2 \end{cases}$$

  $$\text{if } w_k = 0, \begin{cases} u'_{3,1} = \mu - T/2 \\ u'_{4,1} = \mu + T/2 \end{cases}$$

  where w_k indicates the embedded binary watermark bit, $|x|$ denotes the absolute value of x.

Figure 5.16 : SVD – U Component Modification Algorithm

The watermark extraction procedure is presented in Figure 5.17, which is the inverse process of the embedding algorithm. The relationship between the third and the fourth entries in the first column of the U matrix is examined. If a positive difference is detected, then the extracted watermark bit is a 1, whereas a negative difference would imply that a watermark bit 0 is extracted. These extracted bit values are used to construct the extracted watermark.

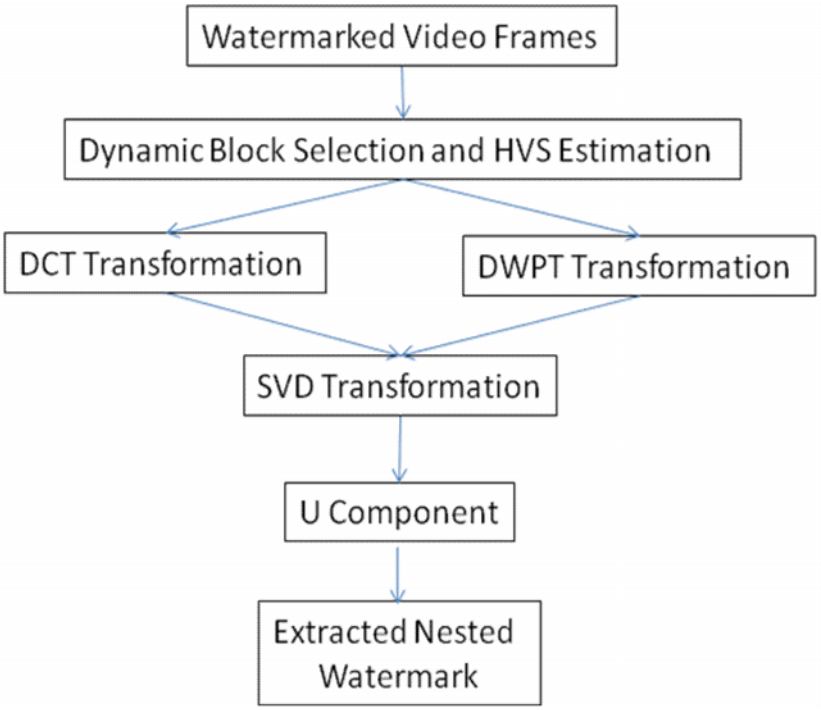


Figure 5.17 : Extraction Process of Transformation Based Algorithms

5.3.2. FPBA Algorithm

The FPBA algorithm consists of steps presented in Figure 5.18. After selecting frames for embedding, in the first step performs a quad-tree decomposition, which is a technique for image representation at different resolution levels. Next, feature points extraction and Local Circular Regions (LCRs) construction are conducted by using Harris-Laplace detector. A mechanism of minimum distance clustering-based feature selection is used to choose a set of non-overlapped LCRs from which geometrically invariant LCRs are completely formed. The histogram and mean statistically independent of the pixel position are calculated over the selected LCRs and are then utilized to embed the watermark. The work is enhanced by removing bad bins in LCR which effects the embedding quality.

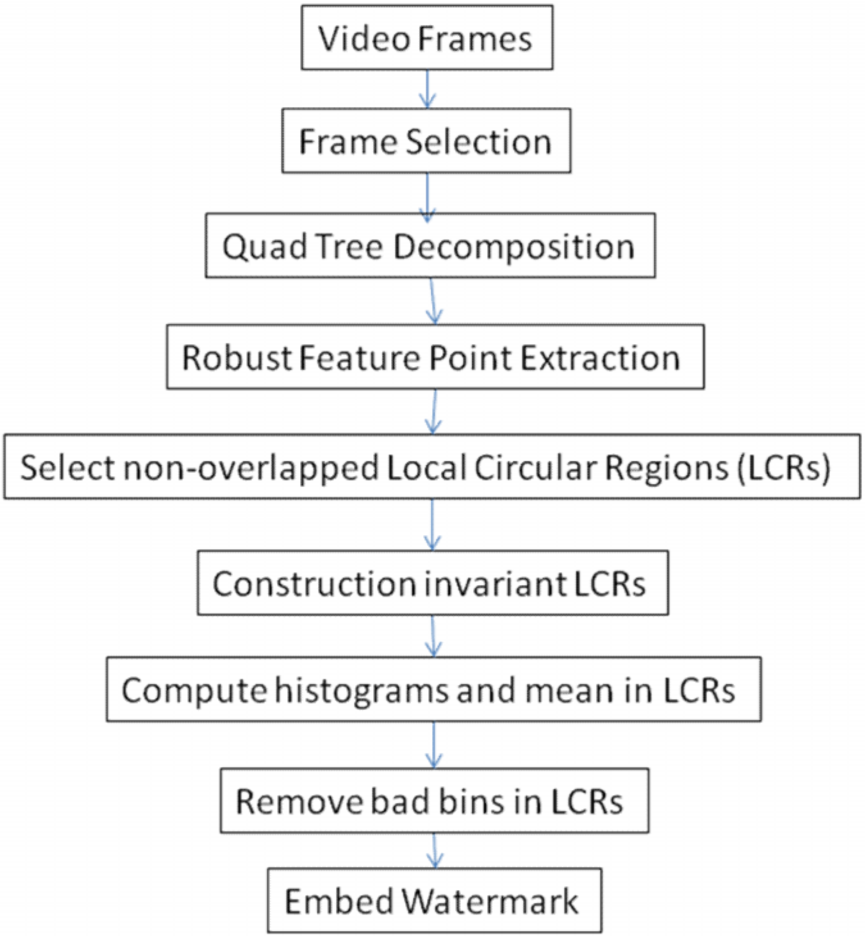

Video Frames
Frame Selection
Quad Tree Decomposition
Robust Feature Point Extraction
Select non-overlapped Local Circular Regions (LCRs)
Construction invariant LCRs
Compute histograms and mean in LCRs
Remove bad bins in LCRs
Embed Watermark

Figure 5.18 : FPBA Algorithm

When embedding watermark, first the relative relationship between groups of two neighboring bins is analyzed. Obviously, the number of pixels in the bin has essential effect on the relative relationship. In some bins, the number is less (zero or a few), which is defined as bad bins. The relative relationships involving the bad bins are unstable and then affect the watermark embedding even if the number of pixels in these bins is only modified slightly. Although the embedding range B can be beneficial to lower the number of the bad bins, the problem has not been solved completely. Especially, the effect produced by the bad bins is more apparent in the LCRs. For this purpose, a threshold to further remove the bad bins in the embedding range B to guarantee embedding watermark in LCRs. This threshold is set to 2 during experiments. The embedding rule is formulated as follows:

Let BIN_1 and BIN_2 be two consecutive bins in the extracted histogram. The number of pixels in these two bins are a and b, respectively. Then, the embedding rules are given by Equation

$$\begin{cases} a/b \geq T \text{ if } w(i)=0 \\ b/a \geq T \text{ if } w(i)=1 \end{cases} \tag{5.12}$$

In the feature extraction algorithm for each candidate point, an iterative algorithm is applied for detecting the location and the scale of feature points. The extrema over scale of the LoG are used to select the scale of feature points. Given an initial point X with scale s_I, the iteration steps are given below.

- Step 1: Find the local extremum over scale of the LoG for the point X_k, otherwise, reject the point. The investigated range of scales is limited to the integration scale
- Step 2: Detect the spatial location a maximum of the strength measure nearest to X for selected integrated scale.
- Step 3: Goto Step 1 if neighbouring integrated scale is not equal
- Since feature points can only provide position information, the neighborhood of the points are required for watermark embedding and detection.
- For each feature point, a LCR is formed. The radius of the LCR is

  $$r = \tau. [\sigma] \tag{5.13}$$

  where . is the rounding operator, σ is the scale, τ is a positive integer to adjust the size of LCR.
- All feature points with scale below 5 or above 10 are ignored
- A distance constraint based on minimum spanning tree is adopted to control the distribution of LCRs.
- Results is a set of non-overlapped LCRs are chosen appropriately

Finally, the FPBA watermark extraction algorithm is given in Figure 5.19.

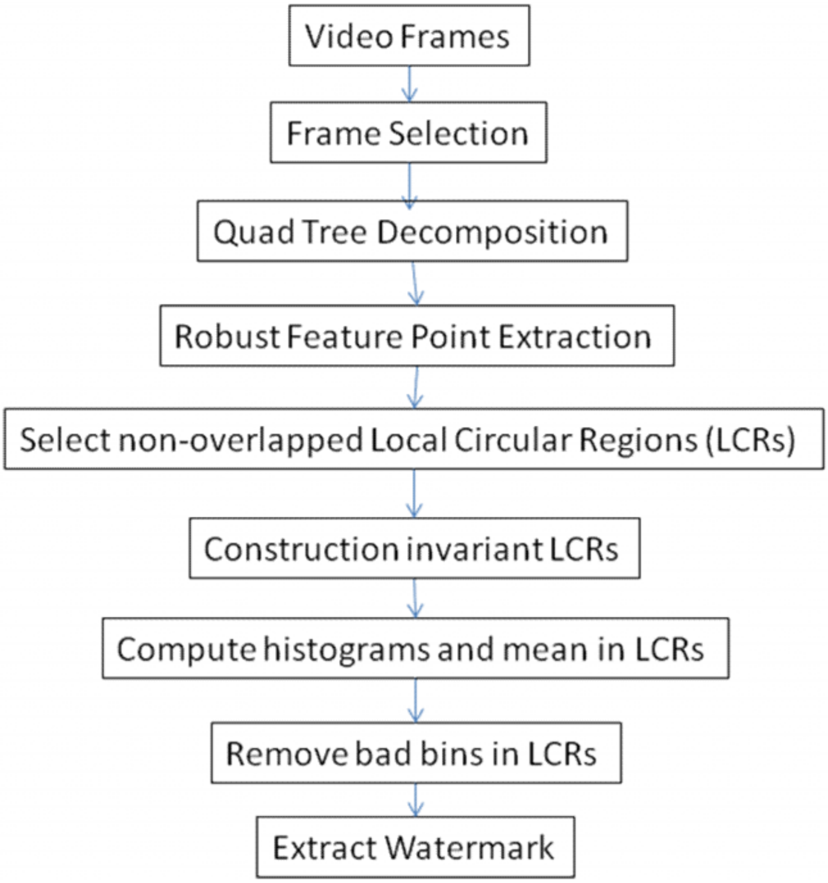

Video Frames
Frame Selection
Quad Tree Decomposition
Robust Feature Point Extraction
Select non-overlapped Local Circular Regions (LCRs)
Construction invariant LCRs
Compute histograms and mean in LCRs
Remove bad bins in LCRs
Extract Watermark

Figure 5.19 : FPBA Watermark Extraction Algorithm

The extraction rule used is given below.

One-bit watermark can be extracted by referring the following equation

$$w'(i) = \begin{cases} 1 & \text{if } a'/b' \geq 1 \\ 0 & \text{Otherwise} \end{cases} \quad (5.14)$$

By repeating the above process, all watermark bits are extracted and the estimated watermark sequence is described as W' ={w‘(i) | I = 1, 2, …, L_w}.

5.4. CHAPTER SUMMARY

This chapter presented watermarking algorithms for both uncompressed and compressed videos. Two algorithms for uncompressed videos are based on static and dynamic block selection was proposed. The algorithms use an amalgamation of techniques like discrete wavelet packet transformation, neural networks and JND for creating a robust watermarking technique. Three algorithms for compressed videos were also described. These algorithms enhanced the transformation based and feature based watermarking process. Thus a total of five algorithms are proposed in this study. Several experiments were performed to evaluate the performance of the proposed algorithms. The results of the experiments are presented and discussed in the next Chapter (Chapter 6, Results and Discussion).