CHAPTER II
REVIEW OF RELATED WORKS

Numerous compression methods both lossy, lossless and hybrid are studied, experimented and reported by several researchers. Some of the relevant compression methods presented by the researchers are discussed in this chapter. Works related to segmentation and wavelet transformations are also discussed.

2.1 LOSSY COMPRESSION METHODS

Vector quantization (VQ), Discrete Cosine Transform and most of the wavelet transforms based compression schemes lead to lossy compression [44][69][124]. The loss occurred in the image is based on the optimal quantization level [128] selected for the compression.

Single-chip cameras usually incorporate a CFA on the sensor to obtain color information. Color interpolation is then needed to recover the color images. Color coding was conventionally implemented after the interpolation process. Two drawbacks inherited are a long processing time and a requirement for a large memory buffer. Direct coding of the sensor data before color interpolation results in enormous artifacts and poor compression efficiency. Tim Tsai.Y (1991) pointed out the problems theoretically and introduced a signal processing method incorporating a DCT (Discrete Cosine Transform) compression scheme to avoid these problems [133]. Simulation results reveal improved compression performance with better image quality and fairly low artifacts. This
approach is moreover suitable for real-time implementation in single chip digital cameras.

Eric A. Gifford et al. (1995), presented a predictive image coder having minimal decoder complexity [36]. The image coder utilizes recursive interpolative DPCM (Differential Pulse Code Modulation) in combination with adaptive classification, entropy-constrained trellis coded quantization and optimal rate allocation to obtain signal-to-noise ratios (SNR’s) in the range of those provided by the most advanced transform coders.

Li.Y and Moloney.C (1997) proposed Synthetic Aperture Radar (SAR) Image compression [74]. The speckle noise is inherent in SAR imaging systems which is an obstacle to image compression. The wavelet domain soft-thresholding technique is implemented to reduce the speckle noise before compression. The embedded zerotree coding algorithm is used to compress the de-speckled images. Better compression ratio with PSNR greater than 40dB can be achieved for typical SAR images with no significant distortion introduced by image compression.

Takao Toi and Mutsumi Ohta (1999) presented a sub-band coding technique suitable for image compression in a single CCD camera with a Bayer Color Filter Array (CFA). In it, they have applied a SSKF (Symmetric Short Kernel Filter) both horizontally and vertically to red and blue color signals and a two dimensional perfect reconstruction filter to green color signals [131]. Here, they have compared this technique to two other image compression
methods. DPCM and the Hadamard transform, each of which also allows an output signal from the CCD in a color camera to be compressed directly with simple logic circuitry and is suitable for use in low cost video conference cameras. Simulation results demonstrate that the sub-band coding offers the best quality (27-30 dB) with a compression ratio of approximately 2 bits/pixel.

Rene J. van der Vleuten (2000) developed a scalable image compression scheme with a good performance complexity tradeoff [114]. It is based on the 8 x 8 block discrete cosine transform (DCT), no quantization or entropy coding. Bit-rate or quality scalability is enabled by encoding the DCT coefficients bit plane from the most significant bit plane to least significant bit plane. The individual bit planes are encoded using rectangular zones. This method offers about the same compression performance as JPEG, but at a lower complexity and with the additional feature of scaling the bit rate by truncating the produced bit string.

Chompoonuch Tengcharoena et al. (2003), proposed an efficient coding technique, called Quadrant Vector Quantization (QVQ) according to wavelet transform [21]. Since then, disparity compensation is a good methodology for stereo image compression that uses one view as a reference to predict another and the difference data is coded.

Many digital color cameras employ a single light sensitive sensor and a color filter array (CFA) with each pixel elements recording intensity information of one color component. The
captured data is interpolated into a full color image, which is then compressed in many applications. Carrying out color interpolation before compression introduces redundancy in the data. Chin Chye Koh et al. (2003), discussed methods and issues involved in the compression of CFA data before full color interpolation [20]. The compression methods described operate on the same number of pixels as the sensor data. To obtain improved image quality, median filtering is applied as post-processing. Furthermore, to assure low complexity, the CFA data is compressed by JPEG. Simulations have demonstrated that substantial improvement in image quality is achievable using these new schemes.

Xiang Xie et al. (2005), presented a method of lossy image compression for digital color image sensors with Bayer Color Filter Arrays [141]. The captured CFA raw data is firstly low-pass filtered in RGB space by a smooth filter followed by the down-sampling operation. Then, the data are transformed from RGB space to YCbCr space. Finally, the filtered data in YCbCr are compressed directly before full color interpolation that introduces redundancy. This method gives lower bit rate and lower complexity than classical interpolation-first image compression methods and other similar compression-first methods.

Andriy Bazhyna et al. (2007), presented an algorithm for lossy compression and decompression of Bayer pattern Color Filter Array (CFA) data which provides low bit rate and reduces computational complexity [13]. The algorithm combines prediction and customized
color space transformation. The combined approach provides better quality reconstructed color image at a given bitrate, reduces computational complexity and prolongs battery life by reducing the processing steps performed in camera. The compression is carried out in the camera while the decompression followed by demosaicing and other ancillary image processing tasks are performed in an external device.

In wireless endoscope capsule, an efficient, low-complexity compression approach for Bayer CFA data is critical for the low power design of the entire system. Xiaowen Li et al. (2007), proposed a compression approach [145] by applying pre-processing before vector quantization [124][134][137]. The CFA raw data are first low pass filtered during pre-processing. Then group of pixels are vector quantized into macros of 9 bits by applying block partition and code mapping in succession. After rearranging, these macros are entropy compressed by JPEG-LS. By control of the pre-processor, both near-lossless and lossy compression can be realized. This approach has a good performance in compression rate as well as reconstructed quality.

Ioannis Kontoyiannis and Christos Gioran (2009) introduced a hybrid algorithm (HYB) that utilizes both the divide and conquer idea and the single database structure of lossy Lempel-Ziv (LLZ) method [46]. The rate distortion performance and implementation complexity are same as the earlier method which is using the divide-and conquer idea but requires much less memory like LLZ.
They introduced a non-universal version of the lossy Lempel-Ziv method (LLZ), proved its optimality for memoryless sources and compared its performance to that of the GVW (Gupta-Verdu-Weissman) divide and conquer approach. Experimental results indicate that the GVW approach often yields better compression than LLZ, but at the price of much higher memory requirements. To combine the advantages of both, they introduced a hybrid algorithm (HYB) that utilizes both the divide and conquer idea of GVW and the single database structure of LLZ. HYB shares with GVW the exact same rate distortion performance and implementation complexity. Like LLZ, HYB requires much less memory, typically by at least one or two orders of magnitude.

Shenqiu Zhang and Cecilia Moloney (2009) proposed grayscale fingerprint image compression [121] based on the hybrid Non-Redundant Contourlet Transform (NRCT). As a directional multi-resolution image representation [26], the contourlet transform can efficiently capture curved and oriented geometrical structures in images. The NRCT is suitable for tracking and efficiently coding oriented structure in images, such as the texture of ridges in fingerprint images. Since NRCT has the advantages of critical sampling and perfect reconstruction. The NRCT is easily compatible with the wavelet transform since it is an extension of the wavelet transform. A new transform which combines the NRCT with the wavelet transform is called the hybrid-NRCT. The compression scheme for fingerprint images using the hybrid-NRCT, yields better
performance than the other transform based fingerprint image compression schemes.

Ali Al-Fayadh et al. (2009), proposed a hybrid lossy image compression technique using classified vector quantizer and singular value decomposition for the efficient representation of medical magnetic resonance brain images [6]. It involves a classifier based gradient method in the spatial domain which employs only one threshold to determine the class of the image block and make use of three AC coefficients of the DCT coefficients to determine the orientation of the block Singular value decomposition was used to generate the classified codebooks. This technique was benchmarked with JPEG2000 standard. The results indicate that this approach can reconstruct high visual quality images with higher PSNR than the benchmarked technique and also meet the legal requirement of medical images archiving.

Zhiwei Xiong et al. (2009), proposed a robust single image super resolution method for enlarging low quality web image degraded by downs-sampling and compression [158]. In order to improve the resolution and visual quality of such web image, a practical solution is given which combines adaptive regularization and learning based super resolution. Analyze the image energy change ratio between significant (e.g., edges, ridges and corners) and insignificant fields during the iterative regularization process. As per the exposed convergence characteristics of the energy change ratio, suitable regularization strength can then be computed
to well balance compression artifacts elimination and vital components preservation. It can be verified that the adaptive regularization can gradually and significantly improve the pair matching precision in learning based super resolution. As a result, their combination successfully removes the quantization noise and meanwhile truly compensates the lost high frequency details, yielding robust super resolution performance in the compression scenario. The results demonstrate that the solution generates visually pleasing magnifications for various web images.

Color images are widely used in computer applications. Uncompressed digital images require substantial storage capacity and transmission bandwidth. At present the efficient image compression techniques are becoming more important with the recent growth of data intensive, multimedia based web applications. DCT [63],[65],[85] has the advantages of real valued, better energy compaction, experimentally observed to work well and coefficients are nearly uncorrelated. Fractal coding is a kind of VQ coding but less than stellar compression ratio for good image reconstruction. Meng Meng and Meijuan Zong (2010), implemented color image compression using Discrete Cosine Transform (DCT), VQ coding and a method that merges DCT and wavelet transform is implemented [80]. Experimental results showed that the performance of new proposed algorithm is effective and can obtain very high compression ratio.
Phat Nguyen Huu et al. (2010), proposed an image compression algorithm that balances energy consumption among nodes in a wireless sensor network cluster [104]. The proposed algorithm uses a Lapped Transform technique, an extended version of the Discrete Cosine Transform. In this method, the compression process is divided into several small processing components, which are then distributed to multiple nodes while considering their residual energy. This scheme not only solves the energy balance problem by coordination of the processing of tasks but also reduces block noise in image compression.

2.2 Lossless Compression Methods

John A. Robinson (2006) presented a complete general purpose method for still-image compression called adaptive prediction trees [54][55][152]. Efficient lossless and lossy compression of pictures, textual, graphics and combined images is achieved by organizing the data in a multicomponent binary pyramid by applying an experimentally optimized nonlinear predictor, utilizing structural redundancies among color components, subsequently coding with hex trees and adaptive RLE or Huffman coders. Color indexing and order statistics pre-filtering are applied adaptively as appropriate. The technique outperforms typical lossless and lossy alternatives.

Ning Zhang and Xiaolin Wu (2006) explore reversible lossless spectral spatial transforms that can eliminate statistical redundancies in both spectral and spatial domains and discover a
particular wavelet decomposition scheme [99], called Mallat wavelet packet transform, is extremely appropriate to the task of decorrelating color mosaic data and propose a low-complexity adaptive context based Golomb–Rice coding technique to compress the coefficients of Mallat wavelet packet transform to compress and store the color mosaic data directly.

Alexander Akimov et al. (2006), presented a lossless compression of color map images by context tree modeling by extending the previous context-tree-based method to operate on color values instead of binary layers [5]. An n-ary context tree is created by constructing a complete tree up to a specified depth and then prune out nodes that do not offer compression improvements. This method outperforms existing methods for a large set of different color map images.

King-Hong Chung and Yuk-Hee Chan (2007) proposed an efficient prediction based lossless compression scheme for Bayer Color Filter Array (CFA) images [66]. It uses a context matching procedure to arrange the neighboring pixels when predicting a pixel and an adaptive color difference evaluation method to reduce the color spectral redundancy while handling red and blue samples. It employs an adaptive codeword generation procedure to adjust the divisor of rice-code for encoding the prediction residues. This compression method achieves a better compression performance than standard lossless CFA image coding methods.
Guangbo Ni et al. (2009), presented an effective low complexity algorithm for onboard lossless compression of hyperspectral images, the algorithm based on hybrid prediction [40]. It is suitable to spacecraft onboard implementation as having much less complexity. The algorithm is mainly composed of three parts to compress the hyper-spectral images. Initially a three dimensional (3D) predictor is used to exploit the spatial correlation and spectral correlation efficiently and then a two dimensional (2D) nonlinear prediction algorithm is applied on the residual image after the 3D predictor. Finally, the residual image is entropy coded by the Rice coding. Performance of the method is compared to other algorithms. This method outperformed other compression algorithms and can be implemented onboard.

Compression based on bitmask improves the efficiency of the dictionary based approaches by recording small differences using bitmasks. Chetan Murthy and Prabhat Mishra (2009) proposed an efficient encoding of bitmasks used in bitmask based compression [17]. It is proved that an n-bit bitmask can be encoded using only n-1 bits. This encoding improved compression efficiency while reducing decompression hardware overhead. This approach improved the compression efficiency by 3% to 10% without adding any additional decompression overhead.

Xiwen Owen Zhao and Zhihai Henry He (2010) acknowledged that the challenge in image compression is to efficiently represent and encode high frequency image structure components, such as
edges, patterns and textures [148]. They have developed an efficient lossless image compression scheme called super spatial structure prediction. This super spatial prediction is motivated by motion prediction in video coding [84][132], attempting to find an optimal prediction of structure components within previously encoded image regions. It is found that this super spatial prediction is very efficient for image regions with significant structure components. The extensive experimental results demonstrated that the scheme is very competitive and even outperforms the state-of-the-art lossless image compression methods.

It has been proved that performance of video coding at low bit rates can be improved by down-sampling a video before compression and up-sampling it after decompression. The down-sampling based coding (DBC) provides more bit budget for DCT coefficients, which preserve more high order coefficients. Minmin Shen et al. (2010), proposed a DBC which uses a modified example based super resolution (SR) algorithm to restore the original resolution of down-sampled video signals [86]. Experiments have shown that the scheme achieved PSNR improvement and better visual quality at low bit rates as compared with the H.264/AVC video coding [10], as well as the DBC using a general locally linear embedding (LLE) method.

Context based predicted residues are computed and compressed using Golomb rice code in order to improve compression ratio [48][89].
2.3 Hybrid Compression Methods

Daniel Greene et al. (1998), proposed a progressive Ziv-Lempel algorithm for image compression [27]. The algorithm gives a progression of compressed versions of a single image. Each stage of the progression is a lossy compression of the image, with the distortion decreasing in each stage, until the last image is losslessly compressed. Progressive encodings are useful in applications such as web browsing and multicast, where the best rate tradeoff is often not known in advance. With progressive encoding, the system can respond dynamically. The algorithm assumes an initial vector quantization step which maps important information of an image, such as intensity values, into higher order bits. The bit planes are then sent successively using a progressive Ziv-Lempel algorithm. A data structuring techniques for selectively coding only those entries in a Ziv-Lempel dictionary that are feasible matches, based on shared knowledge of the data transmitted in earlier stages is proposed. This technique, when applied to sample images on the web, gives significant improvements over interlaced GIF in both image quality and compression rate.

Zhou Wang et al. (2000), proposed a hybrid image coding based on partial fractal mapping [160]. The fractal image compression method models an image by means of a contractive mapping called fractal mapping in the image space.

Sunil Bhooshan and Shipra Sharma (2009) proposed a hybrid approach to compression [130]. The image is filtered by a high pass
filter to find the areas that have details, then an effective scheme based on Huffman coding and adaptive interpolation is used to encode the image. A good compression ratio is obtained.

Shuhui Wang and Tao Lin (2009) proposed a Unified LZ and Hybrid Coding (ULHC) method [123] for compound image and video compression [24][28][29]. The method is macro-block based. Initially each macro-block is coded simultaneously by both H.264 [18][132] and gzip, then rate distortion optimization is used to select either H.264 coding or gzip coding as the final coding of the macro-block. To improve the compression performance of ULHC, gzip uses the most recent 32k bytes of reconstructed macro-block data as the dictionary. Moreover, de-blocking is disabled if at least one macro-block in an image is coded by gzip. This method provides up to 18 dB higher PSNR than H.264, while for text and graphics mixed images, the rate-distortion performance improvement is more significant. Another important feature is that ULHC can achieve partial lossless and partial near-lossless coding with a very high compression ratio.

Jun Wang et al. (2009), presented a Hybrid Block Truncation Coding (HBTC) for color image compression [60]. In the HBTC algorithm to improve the compression ratio of the basic BTC, only luminance bit-map is employed to represent the edge information of the coding block. Moreover, an efficient adaptive quantization coding (AQC) is employed to compress the two chrominance levels further. HBTC performs equally well as the BTC in case of subject
visual quality and considerably improves the compression ratio of BTC from 2.88:1 to 6.00:1 with the limited performance losing about 0.66dB in PSNR.

Hemasundara Rao.C and Madhavi Latha.M (2009) proposed a novel reversible blockade transform for hybrid image compression [41]. The technique implemented over regions of interest (ROIs), is based on selection of the coefficients that belong to different transforms, depending on the coefficients proposed. This method allows codification of multiple kernels at various degrees of interest, arbitrary shaped spectrum and flexible adjustment of the compression quality of the image. No standard modification for JPEG2000 decoder was required. The method was applied over different types of images and the results show a better performance for the selected regions, when image coding methods were employed for the whole set of images.

Jong-Yun Kim, Chun-Ho Yi and Tae-Yong Kim (2010) proposed a region of interest (ROI) centered compression method [57]. A center of ROI is tracked using Dynamic Kalman Filter (DKF) Algorithm. ROI macro blocks (MBs) are determined and quantized each MB adaptively with rate control. Experimental results showed increased clearness in the ROI than uniform quantization methods while maintaining stable bit-rate.

Qiusha Min and Robert J.T. Sadleir (2010), proposed a novel lossless 3D compression scheme for medical image delivery based on Prediction by Partial Matching (PPM) in combination with 3D
JPEG-4 compression [108]. The proposed method is efficient and practical in terms of both compression ratio and decompression speed for transmission of data over the Internet.

Parveen Banu and Venkataramani (2011) proposed a hybrid image compression scheme based on decomposing the data using daubechies-4 wavelet in combination with the lifting scheme and entropy encoding for improved compression ratio [101]. Set Partitioning In Hierarchical Tree (SPIHT) based hybrid compression is implemented and tested [95] for improved compression ratio.

2.4 Segmentation

Segmentation is one of the major challenging tasks in image processing as it involves to certain extent a semantic understanding of the image. Segmentation based on Quadtree [155] is used in variable rate vector quantization for compression.

Albert et al. (2001), presented an unsupervised color segmentation procedure to separate skin color detected pixels into a set of homogeneous regions which can be employed in face recognition applications or any other application which may employ color image segmentation [4]. The algorithm is carried out in a two phase processing, where the chrominance and luminance information are used successively. For every phase an algorithm which combine pixel and region based color segmentation methods is used. The algorithm is verified to be efficient under a good number of test images.
Qiuxiao Chen et al. (2004), presented a fast and accurate segmentation approach [109]. Primarily, a homogeneity gradient image was produced. Then, an efficient watershed transform was employed to gain the initial segments. Finally, an improved region merging approach was proposed to merge the initial segments by taking a strategy to minimize the overall heterogeneity increased within segments at each merging step and the final segments were obtained. Compared with the segmentation approach of a commercial software eCognition, the proposed one was a bit faster and a bit more accurate when applied to the Quickbird images.

Kanchan Deshmukh et al. (2006), presented “Adaptive color image segmentation using fuzzy min-max clustering (ACISFMC)”. The work is an application of Simpson’s fuzzy min-max neural network (FMMN) clustering algorithm [64]. ACISFMC uses a Multilayer Perceptron (MLP) like network which performs color image segmentation using multilevel thresholding. Threshold values used for finding clusters and their labels are found automatically using FMMN clustering technique. FMMN clustering [81][147] technique uses a hyper-box fuzzy set concept. Fuzzy entropy is used as a tool to decide a number of clusters. ACISFMC uses saturation and intensity planes of HSV (Hue, Saturation and Value) color space to segment the color image. In this method, neural network is employed to find various objects automatically from an image. One of the good features of this method is that, it does not engage a priori information to segment a color image. The algorithm
is found to be robust and comparatively computationally economical for a larger range of color images.

LI Jiuxian XIA et al. (2006), addressed the problem of face detection in color image. A coarse-to-fine approach to face detection is presented [73]. Initially a novel self-skin segmentation algorithm is used for skin detection, instead of conventional skin color model. In the second step, edge information and mathematical morphology method are integrated to progressively restrict the possible candidate face regions to smaller areas. Finally, support vector machine based on a wavelet basis is used for face verification. Face images for test are classified as simple, mid-complicated and complicated images. Experiments show that the algorithm presented is of accuracy and reliability.

The morphological segmentation paradigm, based on the watershed transform and markers has been extremely successful, both for interactive and for automatic segmentation. Though many algorithms were proposed for watersheds in the literature, most of them are based on binary images, for finding water catchments basins. Nagaraja Rao.A et al. (2006), presented a new method of finding watersheds on grey level image using 5 X 5 and 3 X 3 masks [97]. To count the number of watersheds on grey levels, a new scheme is used for selecting the height of the peak points from where water starts falling, to the central point. The
algorithm is applied on human images and textures and a good segmentation has resulted.

Xiaohui Yuan et al. (2007), described a gradient vector flow driven active shape method for model based image segmentation [144]. Active shape algorithm retains the shape feature of the interested object and its performance relies heavily on initialization. Because of a lack of global regulation, the control points tend to be trapped in a local optimum in searching. This method uses the gradient vector flow of an image to guide the optimization process. The control points of an active shape are steered by the direction and the magnitude of gradient vectors. Experiments demonstrated great improvement in finding the global optimum and resulting correct segmentation.

Ilya Levner and Hong Zhang (2007) presented a novel approach for the construction of topographical function and object markers employed within watershed segmentation [45]. Typically, marker driven watershed segmentation extracts seeds indicating the existence of objects or background at explicit image locations. The marker locations are then taken to be regional minima within the topological surface and the watershed algorithm is applied. In contrast, this approach uses two classifiers, one trained to produce markers, the other trained to produce object boundaries. Machine learned pixel classification facilitates the algorithm to be directly applicable to both single channel and multi-channel image data.
Additionally, rather than flooding the gradient image, the inverted probability map created by the second classifier mentioned above as input to the watershed algorithm is used. Experimental results demonstrate the better performance of the classification driven watershed segmentation algorithm for the tasks of image based granulometry and remote sensing.

Active contours or snakes have been extensively used in image processing applications. Typical barriers to consistent performance include limited capture range, noise sensitivity and lower convergence to concavities. Bing Li et al. (2007), proposed an external energy for active contours, called vector field convolution (VFC), to discover a superior solution to the problems [15]. VFC is determined by convolving the edge map produced from the image with the user defined vector field kernel. Two configurations for the amplitude function of the vector field kernel were proposed and an analytical method to approximate the parameter of the amplitude function has presented. Mixed VFC is established to reduce the potential leakage problem caused by selecting unsuitable parameters. The advantages of this improvement include better noise robustness, reduced computational cost and the flexibility of creating the energy field.

Pierre-Marc Jodoin et al. (2007), put forward a novel fusion framework that mixes together label fields instead of observation data [105]. The framework takes as input two label fields. They are a quickly estimated and to be refined segmentation map and a
spatial region map that exhibits the shape of the main objects of the scene. These two label fields are fused together with a global energy function that is minimized with a deterministic iterative conditional mode algorithm. The energy function may implement a pure fusion strategy or a fusion reaction function. In the latter case, a data related term is used to make the optimization problem well posed. The conceptual simplicity, the small number of parameters, the use of a simple and fast deterministic optimizer that admits a natural implementation on a parallel architecture are among the main advantages of this approach. The framework is adapted to various computer vision applications [75][78] among which are motion segmentation, motion estimation [52] and occlusion detection.

Kyungsuk (Peter) Pyun et al. (2007), developed a multiclass image segmentation method using Hidden Markov Gauss Mixture Models (HMGMMs) and provided examples of segmentation of aerial images and textures [71]. HMGMMs incorporate supervised learning, fitting the observation probability distribution given to each class by a Gauss mixture estimated using vector quantization with Minimum Discrimination Information (MDI) distortion. They formulated the image segmentation problem using maximum posteriori criteria and found the hidden states that maximize the posterior density. They have estimated both the hidden Markov parameter and hidden states using a stochastic expectation maximization algorithm. The results demonstrate that HMGMM provides better classification in terms of Bayes risk and spatial
homogeneity of the classified objects than do several popular methods, including classification and regression trees, learning vector quantization, causal Hidden Markov Models (HMMs) and multiresolution HMMs. The computational load of HMGMM is similar to that of the causal HMM.

Jundi Ding et al. (2008), presented a Connected Coherence Tree Algorithm (CCTA) for image segmentation with no prior knowledge [62]. It aims to find regions of semantic coherence based on the proposed neighbor coherence segmentation criterion. More specifically, with an adaptive spatial scale and an appropriate intensity-difference scale, CCTA often achieves several sets of coherent neighboring pixels which maximize the probability of being a single image content (including kinds of complex backgrounds). In practice, each set of coherent neighboring pixels corresponds to a coherence class (CC). The fact that each CC just contains a single equivalence class (EC) ensures the separability of an arbitrary image theoretically. In addition, the resultant CCs are represented by tree-based data structures, named connected coherence trees (CCTs). In this sense, CCTA is a graph based image analysis algorithm, which expresses three advantages.

- Its fundamental idea, neighbor coherence segmentation criterion, is easy to interpret and comprehend.

- It is efficient due to a linear computational complexity in the number of image pixels.
Both subjective comparisons and objective evaluation have shown that it is effective for the tasks of semantic object segmentation and figure-ground separation in a wide variety of images.

Those images either contain tiny, long and thin objects or are severely degraded by noise, uneven lighting, occlusion, poor illumination and shadow.

Krstinic.D et al. (2010), presented a novel image segmentation technique based on the nonparametric clustering procedure in the discretized color space [68]. The discrete probability density function is computed in two steps. Multidimensional color histogram is produced, which is afterwards used to obtain final density value using the variable kernel density estimation technique.

Segmentation is achieved by mapping revealed range domain clusters to the spatial image domain. This method is highly efficient, running in time linear to the number of the image pixels with low constant factors. The output of the algorithm can be applied for a specific application to make simple the integration with other image processing procedures.

Quantitative assessment on a standard test dataset proves that the quality of the segmentations provided by the method is comparable to the quality of the segmentations generated by other broadly approved low-level segmentation technique, while running times are several times faster.
2.5 Edge Detection

Sugata Ghosal and Rajiv Mehrotra (1994), presented a parametric model-based approach to high-precision composite edge detection using orthogonal Zernike moment-based operators [129]. The projections of depth or orientation discontinuities in a physical scene or mutual illuminations and specularities in the neighborhood of convex or concave object edges result in intensity edges in an image which cannot be modeled as step edges. These edges are known as composite edges and typically are combinations of steps and roof edges. They have dealt with two types of composite edges, namely generalized step and 2D staircase edges.

A 2D generalized step edge is modeled in terms of five factors: two gradients on two sides of the edge, the distance from the middle of the candidate pixel, the direction of the edge and the step size at the location of the edge. A 2D staircase edge is modeled in terms of two steps located at two points within the mask and the edge direction. A staircase edge is formed if the steps are of contradictory polarities whereas a staircase edge results from two steps having the identical polarity. Two complex and two real Zernike moment dependent masks are projected to resolve factors of both the 2D edge models. For a given edge model, estimated factor values at a point are applied to detect the occurrence or non-existence of that type of edge.
The technique of scale multiplication is analyzed by Paul Bao et al.(2005), in the construction of Canny edge detection[102]. A scale multiplication function is described as the product of the responses of the detection filter at two scales. Edge maps are constructed as the regional maxima by applying threshold the scale multiplication results. The detection and localization principle of the scale multiplication are inferred. At a small loss in the detection principle, the localization principle can be much improved by scale multiplication. The product of the two principles for scale multiplication is better than that for a single scale, which leads to better edge detection performance.

Yang Zhang and Peter (2006) investigated the operating point of the Canny edge detector which minimizes the Bayes risk of misclassification [150]. By considering each of the sequential stages which constitute the Canny algorithm, concluded that the linear filtering stage of Canny, without post processing, performs very poorly by any standard in pattern recognition and achieves error rates which are almost indistinguishable from a priori classification. They have demonstrated that the edge detection performance of the Canny detectors due almost entirely to the post processing stages of non maximal suppression and hysteresis thresholding.

Olivier Laligant et al. (2007), addressed the problem of the influence of neighbor edges and their effect on the edge delocalization while extracting a neighbor contour by a derivative approach [100]. The properties to be fulfilled by the regularization
operators to minimize or suppress this side effect are deduced and the best detectors are pointed out. The study is carried out in 1D for discrete signal. They have showed that among the derivative filters, one of them can correctly detect their model edges without being influenced by a neighboring transition, whatever their separation distance is and their respective amplitude is. A model of contour and close transitions is presented and used. The noise effect on the edge delocalization is recalled through one of the Canny criteria.

Edge detection is a very important process for many image processing applications, especially in Car License Plate Detection and Recognition Systems (CLPDRS). The need to distinguish the desired details is a very important pre-process in order to give good results in short time processing. Abbas M. Al-Ghaili et al. (2008), proposed a new and fast Vertical Edge Detection Algorithm (VEDA) which is based on the contrast between the grayscale values [2]. Once, input gray image was binarized by using adaptive threshold, Unwanted Lines Elimination Algorithm (ULEA) was applied. After that, a VEDA was applied for experimental images. Then, implementation on the application is performed and discussed in order to confirm that VEDA is robust for highlighting license plate details easily. The results revealed accurate edge detection performance and demonstrated the great efficiency of using VEDA in order to highlight license plate details. Finally, VEDA showed that it is faster than Sobel operator by about 7-9 times.
Feature detection in image data has been examined for several years and recently the problem of processing images containing unevenly distributed data has happen to prominent. Range data are currently frequently applied in the fields of image processing and computer vision. However, due to the data unevenness found in range images that takes place with a range of image sensors, direct image processing, in particular edge detection, is an important problem. Normally, uneven range data would require to be interpolated to a standard grid prior to processing. An example of an edge detection method that can be applied to range images is the scan-line estimation, but this does not use exact data locations. Sonya A. Coleman et al. (2010), presented novel Laplacian operators that can be applied directly to unevenly distributed data and in particular the focus is on application to unevenly distributed 3D range data for the purpose of edge detection [125]. Within the data distribution framework generally occurring in range data acquisition equipments, results demonstrate that the technique works well over a range of levels of unevenness of data distribution. The use of Laplacian operators on range data is also found to be much less susceptible to noise than the usual application of Laplacian operators on intensity images.

2.6 Wavelet Transformations

The Discrete Wavelet Transform (DWT) has many useful properties when applied to image compression [42][53][76]. The multiresolution decomposition is of complexity O(n) and conserves
the geometric image structure within each subband. A tree structured coding scheme can efficiently exploit the inherent correlation in the subband representation. Mohamed A. El-Sharkawy et al. (1997), introduced an algorithm which incorporates a fast tree-structured quantization scheme and partial search vector quantization [88]. The algorithm described a novel quantization thresholding scheme which uses the DWT to decompose an image into octave wide frequency bands, then quantizes the coefficients using a "look ahead" measurement of the image based on the low frequency sub-image inherent in the DWT. This algorithm then uses vector quantization to code the thresholded coefficients of the decomposed image. A partial search vector quantization algorithm is used to increase the speed of the quantization by using a sorted table of the energy content of the code vector. Each subband has an associated codebook which is generated using the Pairwise Nearest Neighbor (PNN) algorithm to produce an initial codebook and then uses the generalized Lloyd (GL) algorithm to arrive at a final codebook.

A considerable number of reversible integer-to-integer wavelet transforms are compared [83] on the basis of their lossless compression performance, lossy compression performance and computational complexity by Michael D. Adams et al. (2000). Of the transforms considered, several were found to perform particularly well, with the best choice for a given application depending on the relative importance of the preceding criteria. Reversible integer-to-
integer versions of numerous transforms are also compared to their conventional (i.e., nonreversible real-to-real) counterparts used for lossy compression. At low bit rates, reversible integer-to-integer and conventional versions of transforms were found to often yield results of comparable quality. Factors affecting the compression performance of reversible integer-to-integer wavelet transforms are also presented, supported by both experimental data and theoretical arguments.

Several reversible integer-to-integer wavelet transforms have been evaluated on the basis of their lossless compression performance, lossy compression performance and computational complexity. For lossless compression, image content is an important factor influencing transform effectiveness. For smooth images, the 5/11-C, 5/11-A and 13/7-T transforms are most effective, while the 5/3 transform performs best for images with a greater amount of high frequency content. In the case of lossy compression, both objective (i.e., PSNR) and subjective performance measures were employed. In terms of PSNR performance, the 9/7-F, 6/14, 13/7-C and 13/7-T transforms yield the best results. At the same time, the 9/7-F, 5/3, 9/7-M, 5/11-C, 5/11-A, 13/7-T and 13/7-C transforms achieve the most favorable subjective ratings. Of the transforms considered, the 5/3 and 2/6 transforms have the lowest computational complexity while the 9/7-F transform has the highest. Unfortunately, the 9/7-F transform, although very good for lossy compression, is significantly higher in
complexity than all of the other transforms and performs poorly for lossless compression.

Obviously, no one transform has superior lossy and lossless compression performance for all classes of images in addition to low computational complexity. Therefore, tradeoffs are involved and the most appropriate choice of transform depends on the needs of the application at hand. For example, in the case of applications requiring low computational complexity, the 5/3 transform is particularly attractive. It performs reasonably well for both lossy and lossless compression and has the lowest computational complexity of all of the transforms evaluated.

Reversible integer-to-integer and conventional versions of the same transforms were also compared. Using reversible integer-to-integer versions of transforms instead of their conventional counterparts used for lossy compression was found to only introduce a slight degradation in subjective image quality in many cases. When transforms associated with FIR (Finite Impulse Response) filter banks are employed, the performance penalty is almost negligible. At low bit rates, the difference in PSNR performance is also small. By examining the performance characteristics of the various reversible integer-to-integer wavelet transforms, it is able to determine several factors that affect the compression performance of such transforms. By considering these factors in the future, one can design new and more effective transforms.
The use of the discrete wavelet transform (DWT) for embedded lossy image compression is now well established. One of the possible implementations of the DWT is the lifting scheme (LS). Because perfect reconstruction is granted by the structure of the LS, nonlinear transforms can be used, allowing efficient lossless compression as well. The integer wavelet transform (IWT) is one of them. This is an interesting alternative to the DWT because its rate distortion performances are similar and the differences can be predicted. This topic is investigated by Julien Reichel et al. (2001) in a theoretical framework [58]. A model of the degradations caused by the use of the IWT instead of the DWT for lossy compression is presented. The rounding operations are modeled as additive noises. The noises are then propagated through the LS structure to measure their impact on the reconstructed pixels. This methodology is verified using simulations with random noise as input. It predicts accurately the results obtained using images compressed by the well-known EZW (Embedded Zero-trees of Wavelets) algorithm. The impact of the IWT when applied to lossy image compression is understood by the investigation.

Chengyi Xiong et al. (2007), presented novel architectures for 1D and 2D discrete wavelet transform (DWT) by using lifting schemes[16]. An embedded decimation technique is exploited to optimize the architecture for 1D DWT, which is designed to receive an input and generate an output with the low- and high-frequency components of original data being available alternately. Based on
this 1D DWT architecture, an efficient line-based architecture for 2D DWT is further used by employing parallel and pipeline techniques, which is mainly composed of two horizontal filter modules and one vertical filter module, working in parallel and pipeline fashion with 100% hardware utilization. This 2D architecture is called fast architecture (FA) that can perform J levels of decomposition for NxN image in approximately $2N^2 \times (1-4^{-J})^3$ internal clock cycles.

Moreover, another efficient generic line-based 2D architecture is proposed by exploiting the parallelism among four subband transforms in lifting-based 2D DWT, which can perform J levels of decomposition for NxN image in approximately $N^2 \times (1-4^{-J})^3$ internal clock cycles. Hence, it is called high speed architecture. The throughput rate of the latter is increased by two times when comparing with the former 2D architecture, but only less additional hardware cost is added. The architectures for 2D DWT are efficient alternatives in tradeoff among hardware cost, throughput rate, output latency and control complexity.

Wenpeng Ding et al. (2007), presented a 2D wavelet transform scheme of adaptive directional lifting (ADL) for digital image compression [137]. Instead of alternately applying vertical and horizontal lifting, ADL carries out lifting based prediction in local windows in the direction of high pixel correlation. Hence, it suits far better to the image orientation features in local windows. The ADL transform is accomplished by existing 1-D wavelets and is
seamlessly incorporated into the global wavelet transform. The predicting and updating values of ADL can be derived still at the fractional pixel accuracy level to achieve high directional resolution, while still maintaining perfect reconstruction. To improve the ADL performance, a rate-distortion optimized directional segmentation scheme was also projected to outline and code a hierarchical image partition according to local features. ADL-based image coding technique outperforms JPEG2000 in both PSNR and visual quality, with the enhancement up to 2.0 dB on images with elevated orientation features.

The wavelet transform as an significant multi-resolution analysis tool [88][139][151] has already been commonly applied to texture analysis and classification. On the other hand, it pays no consideration to the structural information while computing the spectral information of the texture image at diverse scales. Zhi-Zhong Wang and Jun-Hai Yong (2008) proposed a texture analysis and classification approach with the linear regression model based on the wavelet transform [159]. The Pyramid-Structured Wavelet Transform (PSWT) and the Tree Structured Wavelet Transform (TSWT) do not consider the correlation between different frequency regions. This method significantly improves the texture classification rate in comparison with the multiresolution methods, including PSWT, TSWT and the Gabor transform.

Yu Liu et al. (2008), presented a new Weighted Adaptive Lifting (WAL)-based wavelet transform [154]. The WAL approach is
designed to solve the problems existing in the previous adaptive directional lifting (ADL) approach, such as mismatch between the predict and update steps, interpolation favoring only horizontal or vertical direction and invariant interpolation filter coefficients for all images. The main contribution of the proposed approach consists of two parts. One is the improved weighted lifting, which maintains the consistency between predict and update steps as far as possible and preserves the perfect reconstruction at the same time. Another is the directional adaptive interpolation, which improves the orientation property of the interpolated image and adapts to statistical property of each image. Experimental results show that the WAL-based wavelet transform for image coding outperforms the conventional lifting-based wavelet transform up to 3.06 dB in PSNR and significant improvement in subjective quality is also observed. Compared with the ADL-based wavelet transform, up to 1.22-dB improvement in PSNR is reported.

The Dual-tree Quaternion Wavelet Transform (DQWT) is a new multi-scale analysis tool for geometric image features. The DQWT is a near shift-invariant tight frame representation whose coefficients sport a magnitude and three phases. Two phases encode local image shifts while the third contains image texture information. The DQWT is based on an alternative theory for the 2D Hilbert transform and can be computed using a dual-tree filter bank with linear computational complexity. To demonstrate the properties of the DQWT’s coherent magnitude or phase
representation, Wai Lam Chan et al. (2008), developed an efficient and accurate procedure for estimating the local geometrical structure of an image [136]. They also developed a multi-scale algorithm for estimating the disparity between a pair of images that is promising for image registration and flow estimation applications. The algorithm features multi-scale phase unwrapping, linear complexity and sub-pixel estimation accuracy.

2.7 Summary

Analyzing various existing lossless and lossy compression methods, it is observed that the compression ratios are not fixed for different images of similar dimensions even though the same compression method is used. This observation leads to the hypothesis that the variation in compression ratio is due to the nature of the images. The nature of the images may be represented or computed by eliciting the various statistical measures of images. The commonly used statistical measures are mean, mode, variance and skewness.

It is also observed that lossless compression is not mandatory for all parts of the image being compressed. Some parts of the image are vital and needs to be restored with no loss and the remaining parts of the images are not so vital and may be allowed certain level of loss. The vitality of the image parts can be identified by the features adaptively. The edges play a major role in the quality of the image. If the edges of the image are lost, it would be difficult even to recognize the image. The background of the image
is normally not so vital compared to the foreground region of the image. The pixels in the image are either belongs to an edge or non-edge. Similarly, a pixel either belongs to background region or foreground region. These two binary features of every pixel is sensed in the proposed work and the pixels are compressed either using lossy or lossless compression methods.