CHAPTER 2

LITERATURE REVIEW OF DATA EMBEDDING METHODS

2.1 INTRODUCTION

Data hiding is an age old technique and has been gaining wide spread attention and significance with increasing threat of insecure data transmission and reception and also data hacking. Data hiding in medical images are of great significance as they are multipurpose based like copyright protection, reduction of bandwidth, tele diagnosis etc., Medical image data hiding has to be carefully dealt with as there cannot be any compromise on the accuracy of data hiding as it may result in wrong diagnosis and ultimately to severe consequences. While each has its own merits and demerits, almost all data hiding techniques revolve around certain key factors like robustness, fidelity, embedding capacity, method of retrieval etc., An extensive survey has been carried out in a pool of transform based techniques for medical image hiding of patient information in an attempt to bring out an ideal choice of transform for appropriate applications.

The rest of the chapter is organized as follows

- Section 2.2 outlines the classification of data hiding techniques and the succeeding sections brief the merits and demerits of various techniques in the area.

- The quantum of related work done in spatial domain is described in section 2.3.
The contribution of researchers in data hiding techniques using frequency domain transforms is highlighted in section 2.4.

Section 2.5 lists the existing transforms which provide resistance to the watermarked image towards external attacks.

The utilization of unique features of transforms being used in a hybrid combination for addressing key issues for optimal embedding is described in section 2.6.

Section 2.7 presents the contributions of researchers to address means of increasing the embedding capacity of the payload inside the host image.

A summary of the literary review and emphasis on the motivation behind current work is presented in section 2.8.

2.2 CLASSIFICATION OF DATA HIDING TECHNIQUES

Any data hiding is classified based on the type of manipulation into two broad categories as spatial domain and frequency domain based. If manipulations are done at the pixel level by manipulating the intensity values, least significant bits etc., then it falls under a spatial domain based category while any manipulation of values at the coefficient level by utilizing certain frequency domain conversion transforms are categorized under frequency domain techniques. A general outline of the classification mechanism based on the type of manipulation performed and some of the important existing techniques under these two domains are illustrated in figure 2.1.
Another method of classification is its division into robust, fragile and semi-fragile. While robust watermarks are able to withstand any external attacks, fragile watermarks get destroyed when exposed to attacks. While robust watermarks could serve the purpose of secret message transmission, copyright protection, fragile watermarks on the other hand serve the purpose of tamper detection. Another classification is based on the method of extraction of watermarks at the receiver side. If the original image is
needed at the receiver side for extraction, it is known as a non-blind extraction process. If it does not require an original image for extraction, such an extraction is called as blind watermarking. The survey has been carried out taking into account certain key factors like robustness, fidelity etc., in terms of peak signal to noise ratio and cross correlation coefficient.

2.3 SPATIAL DOMAIN DATA HIDING TECHNIQUES

Spatial domain technique based data hiding involve manipulation of pixel values and has commenced since the early 1980’s with Ingemar J. Cox et al technique (1997) for secure spread spectrum watermarking (SSSW) for multimedia which has the property of tamper resistance followed by Jiri Friedrich (1998), who has utilized the complementary robustness properties of both low frequency watermarks and spread spectrum generated watermarks to obtain a watermarked image capable of surviving an extremely wide range of severe image distortions. Athanasios Nikolaidis et al. (2001) technique is a region based watermarking where the robust regions are carefully selected through pre processing stages utilizing segmentation and clustering. Acharya et al. (2004) have utilized the least significant bit replacement concept to perform the embedding of electronic patient information inside the medical image. Hsien et al. (2005) provided a vector quantization based method to reduce the storage and transmission time. Celik et al. (2005) technique is based on a least significant bit replacement with the bits of the payload. Giakoumaki A., et al. (2004) and Alessia De Rosa et al. (2006) have discussed the authentication and labeling of medical images through data hiding for health care management which forms the motivation behind this work.

Navneet Mandhani et al. (2005) have introduced a code division multiple access scheme for hiding data in monochrome images. Huang et al. (2005) have suggested chrominance utilization based watermarking technique, where the payload is inserted into the directional coefficient values of the color image and the results show good perceptual
invisibility and robustness towards filtering, compression and cropping. Neminath et al. (2009) utilized the histogram of images to develop a watermarking technique found to exhibit a good fidelity. Osamah Al – Qershi et al. (2009) have suggested a region of interest (ROI) based data hiding in medical images and is shown to be tamper resistant. A recent advancement in the spatial domain methods are the utilization of luminance values of an image proposed by Jamal Hussein (2010) which exhibited good tolerance towards JPEG compression and rotation attacks. Chin Feng Lee et al. (2011) have put forward reversible data hiding technique utilizing a vector quantization compression code and is able to restore the original image without any distortion.

2.4 FREQUENCY DOMAIN DATA HIDING TECHNIQUES

Even though the above mentioned spatial domain techniques provide a good fidelity, the quality of image tends to degrade with increasing aggressive image processing operations such as increased compression, scaling, filtering and increased levels of noise as spatial domain techniques tend to operate on raw pixel values as such. Normally the transformation divides the image into high frequency and low frequency components with mid band frequency components in between. This decomposition or separation of frequencies also provides the user increased flexibility in choice of an ideal embedding location depending on the application. If the watermarked image tends to be compressed during its path, the watermarks could be embedded into the low or mid frequency components. On the other hand, if the watermarked image tends to be passed through a channel prone to high levels on noise, then it is desirable to embed in the low frequency components of the image. The heart of any frequency domain watermarking is the transform used for decomposition and reconstruction.

Many transforms exist such as the Fast Fourier Transform (FFT), Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Contourlet Transform (CT), Curvelet Transform, Ridgelet Transform (RT), Shearlet Transform (ST) etc., Choice of
appropriate transform for specific application is truly a challenge to obtain optimal embedding results due to unique properties of different transforms.

The mid band coefficients of a DCT transformed host image are chosen to be the embedding location for embedding a pseudo random sequence corresponding to the payload in the technique proposed by Mauro Barni et al. (1998). The resulting watermarked image proves to be robust towards aggressive image processing operations like compression, medial filtering etc., Deepa Kundar et al. (1998) have utilized the multi-resolution properties of the wavelet transforms for data hiding using a blind algorithm for extraction. Shinfeng et al. (2010) have reported a robust DCT based data hiding technique which exhibits a high degree of robustness towards a wide range of aggressive image processing operations. Another blind approach was developed by Jian Guo Cao et al. (2001), using a redundant wavelet transforms which was adapted to the features of the cover image. An optimal recovery of watermark which was noise corrupted was proposed by Nam Yong et al. (2001) utilizing the wavelet vaguelette decomposition (WVD) along with wavelet shrinkage. Wang et al. (2002) technique is based on the DWT and is proved to have good robustness towards certain image processing operations simulated for real time attacks. Xuan et al. (2002) technique is based on conversion of spatial domain image into the frequency domain by utilizing the integer wavelet transform which is found to show satisfactory robustness towards certain types of attacks.

With the advent of neural networks, Fan Zhang et al. (2005) put forward a watermarking technique based on Hopfield network which was blind algorithm but retrieval getting lossier with multiple watermarks. A non-blind approach was proposed by El Taweel et al. (2005) based on Hadamard transform where higher levels of security were obtained by using a private key but it required the presence of original image during the detection process. Much more precision on selection of embedding locations was
achieved using Yong Wu et al. (2005) using a threshold selection method and the results showed good robustness and also visually imperceptible.

A middle band coefficient exchange system was introduced by Vikas et al. (2007) for a monochrome watermark. More advancement has been done with the advent of wavelet transforms as they are highly utilized for multi-resolution analysis of a signal. They also provide more flexibility in terms of choice of ideal embedding locations and can be adapted to the human perception. The wavelet transform was extended towards a Fractional wavelet transform approach which offers a quite flexible and optimal security as the wavelet packet filters are used as the key. Xiang et al. (2008) utilizes the statistical properties of the low frequency domain of the cover image for embedding the watermark bits which is found to be invariant towards a wide range of image processing attacks. Elazhary et al. (2010) technique is a DCT domain based data embedding and is robust towards certain aggressive image processing operations and utilized for copyright protection applications.

Emmanuel J. Candes et al. (2002) introduced these new multiscale constructions for extracting many useful geometric features. Even though, Curvelet transforms for data hiding are at its preliminary stages, some relevant applications put forward by Birgir Bjorn Saevarsson et al. (2004), Minh M. Do et al. (2005) Demin Wang et al. (2006), Myungjin Choi et al. (2006), Peining Tao et al. (2007), Jean Luc Starck et al. (2008), Chune Zhang et al. (2008), Jagadeeswar Reddy et al. (2008), Chune Zang et al. (2008), Mohammed Meselhy et al. (2010) have shown that Curvelet transforms and Contourlets have a significant edge over the other conventional techniques. A further advancement of the Curvelet transforms is the Shearlet transforms put forward by Sheng Yi et al (2009) predicts the behavior of edges towards multi scale representations.

Minh Do et al. (2005) and Chandra Mohan et al. (2008) have put forward another transform for efficient directional multi resolution representation through the Contourlet
Transform which is capable of bringing out the directional properties of each of the coefficients.

2.5 ATTACK RESISTANT DATA HIDING TECHNIQUES

Once the choice of transform has been made suitable and compatible to the application, the most important requirement following it is that the embedding algorithm should be stable. The stability is best when the embedded image or content is able to withstand against intentional and unintentional attacks that intervene in the communication channel. Jonathan et al. (2001), Frank Hartung et al. (1999), Claude Desset et al. (2002) and Raphael et al. (2008) illustrate a wide range of attacks predominant in the transmission channel. Noise is a common obstacle present which is classified as an unintentional attack while cropping, filtering, scaling, rotating, compression are classified as intentional attacks as they are done on the embedded image in an attempt to destroy the payload or retrieve the information in some way or the other. Hence, it is necessary to test the stability of the embedding algorithm by subjecting the watermarked image to all the above attacks and measuring its robustness. As mentioned in previous sections, normalized cross correlation coefficient is mostly used to evaluate the robustness where a value towards 1 indicates a strong embedding algorithm while values toward 0 indicate weakness in the algorithm.

Embedding has also been carried out into the radon transform coefficients which show a substantial improvement in signal to noise ratios. Srdjan Stankovic et al. (2001) have introduced a radon based approach to incorporate translation invariance properties to the watermark. Lin C.Y et al. (2001) have proposed a RST invariant watermarking technique by utilizing the Fourier transform and transforming them to log polar coordinates which are quite resilient towards rotation, scaling and translation attacks. Chin Chen Chang et al. (2005) proposing a semi blind approach by using singular value decomposition method SVD with the watermarked image is found to be strongly
resistant towards attacks and also could be used for tamper detection applications. This was followed by Ghazy et al. (2005) where a block by block based SVD watermarking is done to show resilience towards RST attacks. Keeping in view the security parameter in the watermarking system, an Arnold iteration transform was utilized by Rongrong et al. (2005) and the resulting watermark was found to be robust against some spatial attacks like contrast changing, scribbling, low pass and high pass filtering and JPEG processing.

Use of a self reference image with the watermark bits embedded into the difference values between the original image and reference image was proposed by Jiang Lung Liu et al. (2006) and is seen to be robust towards JPEG lossy compression, filtering and noise addition. Dugelay J. L et al. (2006) technique is a reference based blind technique which involves modulation of a separate bit stream in accordance with the payload bits. It is found to be robust towards geometric distortion attacks. Zain J.M., et al. (2007) have put forward a reversible watermarking technique for digital imaging and communications in medicine images by embedding data into the regions of non region of interest (NROI). Ming-Chiang Hu (2007) proposes a blind, lossless and two phase data embedding method in the spatial domain which exhibits good tolerance towards various attacks especially to geometric attacks. Tong et al. (2008) utilizes a fast independent component analysis (ICA) algorithm based watermarking technique for enhancing the robustness towards geometric attacks. Wu et al. (2008) technique involves interleaving the authentication message and the cover image bits using the modulo operation on a block by block based watermarking. It is effectively used for tamper detection applications.

Xiang-Yang Wang et al. (2009) have utilized the pseudo Zernike moments and Krawtchouk moments to develop a robust image watermarking algorithm to specifically address geometric distortion. An embedding using amplitude modulation scheme was put forward by Chao Hung et al. (2009) which were quite invariant towards geometric attacks. A non negative matrix factorization along with wavelet transform has been
exploited by Mohammed Ouhsain et al. (2009) showing a good resiliency towards intentional and geometric attacks and better visual imperceptibility.

Osamah Al – Qershi et al. (2011) have suggested a reversible watermarking scheme using difference expansion of pixels for tamper detection and also for recovery of the watermark. A non blind approach for copyright protection robust to a wide range of image distortions was proposed by Yong Zhang et al. (2010) based on mean quantization. It also held a good tradeoff between the embedding capacity and image quality. Lin et al. (2010) addresses the robustness towards JPEG compression attacks using the energy compaction feature of DCT transform. Nisar Ahmed Memon et al. (2011) technique casts a robust watermark into region of non interest for providing robustness and a fragile watermark into region of interest for tamper detection applications. Although it provides satisfactory results in robustness and imperceptibility, it fails to address the embedding capacity issues.

2.6 HYBRID TRANSFORMS FOR DATA EMBEDDING

As mentioned in section 2.4 that the transforms are unique in nature and it can be rightly justified by observing the properties of them in the following sections. Since, efficiency of a data embedding system is all about finding the optimal tradeoff between robustness, perceptual invisibility and embedding capacity, the essential properties of different transforms discussed in the previous sections have been combined in a hybrid combination to address the optimality criteria to the maximum extent possible. In line with this concept, many techniques have been put forward which have shown to exhibit performance features. Frank et al. (1999) have introduced a watermarking scheme to increase the watermarking capacity and also to provide a double kind of protection to the watermarking through his watermark splitting approach. Kouros Jafari-Khouzani et al. (2005) technique combines DWT and SVD in a hybrid combination and is robust towards rotation, scaling and translation attacks. A hybrid combination of DWT and DCT by Ali
Al – Haj et al. (2007) and visual model based DCT and DWT proposed by Ahmed A. Abdulfetah (2010) have shown robustness towards compression attacks while a combinatorial DWT and SVD approach by Gaurav Bhatnagar et al. (2009) have shown visual invariance towards scaling and translational attacks. The hybrid combinations of Contourlet transform and SVD to address the robustness issues and invariance towards RST attacks proposed by Venkatanarasimhulu et al. (2011) provide an effective motivation and platform to exploit the directional feature of the Contourlet transform and also to check the compatibility of the Contourlet transform towards other transform in a hybrid combination.

2.7 EMBEDDING CAPACITY ENHANCEMENT TECHNIQUES

Another critical criterion is the estimation of embedding capacity which is a measure of how much of information could be packed or embedded inside the image without causing any visual degradation or affecting the fidelity. The embedding capacity issues discussed by Servetto et al. (1998) have provided an insight into the various aspects of increasing the embedding capacity given a cover image. Brian Chen et al. (2000) have established a tradeoff between the embedding capacity and quality of watermarked image through his quantization index modulation methods (QIM). Weng .S et al. (2007) propose a distortion less image data hiding algorithm based on integer wavelet transform that can invert the stego-image into the original image without any distortion after the hidden data are extracted. This algorithm hides data into one or more middle bit planes of the integer wavelet transform coefficients in the middle and high frequency sub bands. It can embed much more data compared with the existing distortion less data hiding techniques and satisfy the imperceptibility requirement. The image histogram modification is used to prevent grayscales from possible overflowing. But this method is computationally intensive and it will be less efficient for reversible data hiding.
Adnan M. Alattar et al. (2003) propose a high-capacity; data-hiding algorithm that lets the user restore the original host image after retrieving the hidden data. Pierre Moulin et al. (2002) used a statistical model comprising of auto regression, wavelet statistical models and block DCT while Fan Zhang et al. (2005) exploited the relationship between watermark capacity and watermark average energy to achieve a tradeoff. A difference expansion of triplets for increasing the embedding capacity has been put forward by Alattar (2003) and Tian J et al. (2003) followed by expansion of quads was suggested by Alattar (2004). A modification of Alattar’s method (2004) by utilizing an integer wavelet transform resulted in a hybrid combination.

Rajendra Acharya et al. (2004) introduced a technique where in the electronic information of the patient commonly termed as the electronic patient information which contains the name and personal details of the patient is being embedded into the medical image thus saving storage space and also providing a high class of electronic security and also preventing any attempt of tampering. Kamstra, L et al. (2005) have suggested a reversible data hiding technique utilizing Sweldens' lifting scheme and increase in embedding capacity is achieved by reconstructing the original image from the watermarked image. Mohammad K. Yaqub et al. (2006) have proposed a modified difference expansion which is a spatial domain based technique for increasing the embedding capacity. Thodi, D.M. et al. (2007) have also suggested a reversible embedding technique which is found to increase the embedding capacity. Weng et al. (2007) have suggested an invertible integer transform approach exploiting the correlations among four pixels in a quad. Companding technique is used in combination to increase the embedding capacity.

Jason Dowling et al. (2008) have compared the performance between the DCT and DWT techniques for medical image embedding of EPR and obtain critical inferences after exposing them to some common prevailing attacks. Lee C.C et al. (2008) have put forward a difference expansion based data embedding technique where the data
embedding capacity is variable from block to block of the cover image. Lin et al. (2008) have developed a data embedding technique based on difference expansion for increasing the data embedding capacity. A pixel based relation is used to determine whether a block is expandable. Kim H.J et al. (2008) have put forward a difference expansion scheme for increasing the embedding capacity.

A histogram modification based reversible data hiding proposed by Wei – Liang Tai et al. (2009) increases the embedding capacity but at the cost of losing the desired optimality in the visual appearance. A block based approach have been proposed by Ju-Yuan Hsiao et al. (2009) where the image is divided into two areas with one being used for data embedding and other for auxiliary information embedding based on edge prediction. This method proves to increase the embedding capacity. A further improvement in embedding capacity was shown by Shih-Chieh Shie et al. (2009) by using compressed VQ Indices of images. Der – Chyuan Lou et al. (2009) proposed a multilayer difference expansion scheme which could be utilized for medical images. Guo X et al. (2009) technique is a reversible data hiding algorithm for medical images, where the embedding capacity is increased by utilizing the concept of difference expansion.

Hsien Wei Yang et al. (2010) have suggested a histogram shifting method based on the differences between the maximum and minimum pixel on a non overlapping block by block basis. Osamah M. Al-Quershi et al. (2011) have put forward a data embedding scheme based on difference expansion between adjacent pixels which is shown to increase the payload capacity being embedded into the cover image. It is essentially a spatial domain technique. Mehdi Fallahpour et al. (2011) have suggested a data embedding in the plain areas of an image determined by use of edge operator and is found to increase the payload capacity that could be cast onto the host medical image.

In 2009, Osamah M. Al-Qershi proposed a reversible ROI based watermarking scheme for DICOM images. In the proposed method, combined two reversible techniques
based on difference expansion for patient's data hiding and protecting the region of interest (ROI) with tamper detection and recovery capability. Patient's data are embedded into ROI, while recovery data are embedded into region of non-interest (RONI). Proposed scheme can be used for hiding patient's data, authenticating ROI, localizing tampered areas inside ROI, and recovering those tampered areas when needed. A combination of two DE techniques developed by Tian J et al. (2008) is adopted in this scheme to gain reversibility and high capacity which has high embedding capacity.

Tian’s (2003) difference-expansion technique is a high capacity, reversible method for data embedding. However, the method suffers from undesirable distortion at low embedding capacities and lack of capacity control due to the need for embedding a location map. D.M.Thodi et al. (2007) proposed a new development by proposing a expansion embedding technique. Chiang K.H et al. (2008) technique involves a reversible watermarking process for restoration of the medical cover image using wavelets.

Ki - Hyun Jung et al. (2009) technique uses a interpolation technique to embed the watermark bits which is found to increase the embedding capacity and also the signal strength. Although, the signal strengths reported using this technique are slightly higher than 36 dB, its applicability to medical image with composite payload might prove to lossy. Jonathan Dautrich et al. (2009) utilize a difference expansion method for Minimizing Corrective Data so as to increase the embedding capacity with minimal errors. The approach presented here identifies pairs that do not need to have a bit in the location map, and constructs a reduced size selection vector in an attempt to increase the amount of embedding space that can be used by the payload. One of the major drawbacks to the difference expansion method is its apparent susceptibility to detection.
2.8 SUMMARY

With all the above aspects discussed so far, the area of digital watermarking is proven to be an evergreen field as long as the security of data transmitted or received is an issue. Since multimedia content are always subject to hacking and attacks, and also increase in bandwidth requirements for communication, data embedding along with encryption stands to be one of the solutions for protection, reduction of bandwidth, time and storage spaces, and also detection of attacks. A recent extension of data hiding towards medical imaging has invited considerable interests from researchers all over due to its significant benefits ranging from telemetry to tele diagnosis. The above thoughts could be extended for embedding the entire patient diagnosis report available in the form of text inside the medical image thus reducing the storage space.

It could be seen that numerous techniques have always been put forward to make the embedding and extraction scheme as optimal as possible. Many algorithms have been reported in spatial as well as frequency domain and also put together in a hybrid combination. Since, any watermarking scheme revolve around three important constraints namely robustness, perceptual invisibility and embedding capacity, a perfect trade off has to be brought about to make the system optimal. It can be observed from the above thoughts that each of the technique gives best result in any one or two of the optimality criteria but at the cost of the other. It can also be observed that most of the above reported techniques are experimented with natural images like lena, cameraman, peppers etc., while a few experimentation have been done with medical images. As already stressed upon the fact that medical images are highly sensitive unlike their natural counterparts, extreme care and systematic methodology has to be taken in establishing the above mentioned trade off. It may be noted that no hybrid technique has been devised so far in a single system which could bring about a balance between the optimality criteria.