CHAPTER 7
CONCLUSION

Watermarking is an exciting technology that facilitates critical business functions that includes content identification, copyright control, behavior tracking, copy protection and forensics. Digital watermarking is a promising way to protect the copyright of digital contents such as text, image, audio, and video. Watermarking can be done in two ways viz., spatial domain technique and transform domain technique. In both the methods, trade-off is involved among imperceptibility, robustness and capacity. Transform domain techniques offers high robustness and imperceptibility when compared to spatial domain techniques. Due to localization in both spatial and frequency domains, wavelet transform is the preferred alternative among all other transforms. To compromise between imperceptibility and robustness, watermark should be embedded in the mid-frequency coefficients. DWT offers two mid frequency bands LH and HL at any level of decomposition. Hence, one may not obtain the perfect mid-frequency coefficients to embed the secret message.

In this thesis, a practical study of DHWT has been presented in image watermarking. Original image was divided into nine subbands with DHWT and the mid-frequency coefficients were obtained accurately. Embedding of watermark in this mid frequency coefficients provided imperceptibility as well as robustness. In this research work, watermarking on
2-D images and spectral images have also been proposed and analyzed. DHWT was extended to complex domain (Complex DHWT) and watermarking based on CDHWT has also been proposed for 2-D gray scale images and spectral images.

In 2-D image watermarking, a 1-level DHWT was taken on the host image and binary watermark image. It divided both the images into nine subbands. SVD was applied to the mid-frequency band of both the images. SVD in combination with DHWT has been proposed to improve the imperceptibility by reducing the number of bits to be embedded. Singular values of the host image were modified by the singular values of watermark image multiplied with suitable strength factor. During extraction process, watermark was reconstructed with the help of the strength factor, sidebands of SVD of mid frequency band and other subbands of original watermark.

Complex Wavelet Transform offers perfect reconstruction, approximate shift invariance and good directional selectivity. Watermarking on 2-D images based on CDHWT has also been proposed. CDHWT combined the advantage of both CWT and M-channel filter bank. Watermark embedding and extraction methods were similar to the previous scheme. CDHWT was taken on the original image instead of DHWT. In both the methods, PSNR value of above 50dB (Lena image) was obtained. Simulation result showed that the proposed method based on DHWT achieves very imperceptibility as compared to the existing methods due to the separation of perfect mid frequency band by DHWT.

Robustness of the watermarking method was evaluated against various attacks. The proposed watermarking scheme was tested with different kinds of attacks such as low pass filtering, median filtering, histogram
equalization, JPEG compression, rotation, cropping and addition of noises like Gaussian, Speckle, Salt & Pepper and Poisson etc. Extracted watermark under noise condition was compared with original watermark. Normalized correlation of above 0.9 was obtained for all kinds of attacks. Experimental result showed that the proposed watermarking schemes achieved very high robustness as compared to other existing methods.

In geometrical attacks, normalized correlation of above 0.9 was obtained for large angle of rotation due to the high value of strength factor. Therefore, it is concluded that the proposed watermarking algorithm resisted the rotational attack efficiently. For copyright protection and authentication, proposed methods have been widely used by photographers, artists, design professionals and agencies to communicate image ownership through copying, manipulation, editing, cropping, compression and decompression all without affecting the quality of the image or the enjoyment of its viewers.

In this thesis, four methods of watermarking algorithm for spectral images have been proposed based on 3-D DWT, CWT, DHWT and CDHWT respectively. 3-D DWT divided the spectral images into eight subbands. Three dimensional dual tree complex wavelet transform was derived from 2-D CWT. 3-D CWT divided the spectral image into dual eight subbands. A 1-level 2-D DWT was applied to the binary watermark. It divided the binary watermark into four subbands. SVD was applied to the mid frequency bands of both spectral host image and the binary watermark. Singular values of host image were modified by the singular values of watermark image multiplied with suitable strength factor. During extraction process, watermark was reconstructed with the help of strength factor, sidebands of SVD of mid-frequency band and other subbands of original watermark. In 3-D CWT based
method, a 1-level 3-D CWT was taken on the host image instead of 3-D DWT.

Watermarking requirements are common for any type of images like 2-D, spectral images etc. After analyzing the experimental results of 2-D DHWT for 2-D image watermarking, DHWT was extended to 3-D in order to watermark the spectral images. 3-D DHWT was developed from 2-D DHWT as similar to that of conventional 3-D DWT extended from 2-D DWT. 3-D DHWT divided the spectral image into twenty seven subbands. A 3-D CDHWT divides the spectral image into dual twenty seven subbands. A 1-level DHWT was taken on the 3-D spectral host image and a 2-D DHWT was taken on the binary watermark image.

3-D DHWT divides the spectral images into twenty seven subbands; similarly, 2-D DHWT divides the binary watermark into nine subbands. SVD was applied to the mid frequency band of both the images. Singular values of host image were modified by the singular values of watermark image multiplied with strength factor. During extraction process, watermark was reconstructed with the help of strength factor, sidebands of SVD of mid-frequency band and other subbands of original watermark. In 3-D CDHWT based method, a 1-level 3-D DHWT was taken on the host image instead of 3-D DHWT.

The proposed four methods of watermarking on spectral images were evaluated based on two main requirements of watermarking scheme, namely, imperceptibility and robustness. DHWT and CDHWT based methods offer better PSNR value when compared to other proposed methods based on DWT and CWT except for Cuprite image. Proposed methods (Moffett image) were compared with other existing methods. Comparison of results showed
that the proposed methods based on DHWT produced very high
imperceptibility. Robustness of the proposed methods was tested against
various attacks and the experimental results were compared with those of the
existing ones. Simulation results showed that the proposed methods based on
DHWT achieved very high robustness and imperceptibility.

7.1 SCOPE FOR FUTURE WORK

Therefore, the proposed watermarking methods for 2-D as well as
spectral images based on DHWT fulfilled the conflicting requirements viz.,
imperceptibility and robustness of the watermarking schemes. A limitation of
the proposed method is that the optimal strength factor was determined
iteratively throughout the thesis. It is suggested that the future work is to
determine the optimal adaptive strength factor in an efficient way, quickly.
Multiple watermarking is also suggested to be carried out in future. In this
thesis a fixed number of binary digits are embedded in the cover image. So,
capacity of watermark is maintained same for simplicity.

Different forms of secret messages such as gray scale image, text,
signature and pseudo-random binary sequence and also different sizes are
suggested to be used in future. Singular values are selected to embed the
watermark instead of singular vectors because square shape watermark is
proposed throughout the thesis. For other sizes of the watermark, singular
vectors may also be considered for embedding to achieve better results.
Efficient embedding of watermark in other subbands may also be developed.
Future method(s) proposed, may be evaluated for other types of input images
such as colour images etc