CHAPTER 6

SUMMARY, CONCLUSION AND FUTURE SCOPE

6.1. Summary and Conclusion

The objective of the research outlined in this thesis is to study the through-the-wall radar images for detection and recognition of shape and size of stationary targets behind the wall, e.g., that can be used to detect objects and or survivors for a mission and/ or after a natural disaster. The motivation for investigating the through-the-wall radar images is to overcome of limitation of Doppler radar that become ineffective for identification of stationary target behind walls due to weak or absence of frequency domain or time domain variation signature of stationary target. Though through wall imaging (TWI) radar has been well studied and applied by many researchers, the focusing problem in the TWI images is still a challenging task showing the object's correct location, shape, and size. This thesis reviews the commonly used migration/focusing methods that have been widely accepted and applied by various researchers in ground penetrating radar imaging and seismic imaging such as back projection, delay and sum beamforming, and frequency-wavenumber. So far, very less work has been reported about the application of these three imaging techniques on measured TWI data for checking the consequences and effect of imaging. Therefore, it becomes essential to explore the application of these algorithms on measured TWI data to evaluate the effect of imaging and compare the performance of their results to select the effective imaging algorithm for approximate shape detection of the target such that the reader can decide which algorithm to use for a particular application of TWI. The performances of these algorithms were compared to each other by testing them over the measured TWI data and a qualitative comparison has been presented. Further, we have applied advanced image processing techniques for which we have developed novel adaptive thresholding method and artificial neural network model for detection and recognition of shape and size of target from the through wall radar images instead of using conventional technique such as geometrical theory of diffraction [Kobayashi (2012), Kobayashi *et al.* (2014)] which is also used to estimate shape of target.

In chapter 3 of this thesis, some of the existing imaging algorithms, like, back projection, frequency- wavenumber and delay and sum beamforming techniques have been critically analyzed to select the effective imaging algorithms. These imaging techniques have been applied on the through-the-wall imaging data and a comparison of obtained images has been carried out. As per our experimental observations with various target samples, a considerable difference between the output images of algorithms from the focusing point of view has been found. Though the considered imaging algorithm can accurately locate position of target, backprojection and frequency-wavenumber algorithms perform poorly in detecting target sizes and shapes compare to delay sum beamforming imaging algorithm. It was observed that peak to signal noise ratio of the formed images using delay sum imaging technique is high compared to the back projection and frequency-wavenumber imaging algorithms. It was also observed delay sum imaging algorithm can be effectively used to detect approximate shape and size of target with low false alarm as compare to frequency-wavenumber and back-projection. However, the processing time required for the delay and sum beamforming algorithm was found to be high as compared to the frequency-wavenumber algorithm.

In Chapter 4, an optimal thresholding technique based on statistics for target shape and size detection in through-the-wall radar images was presented using curve fitting and genetic algorithm based multi-objective optimization. The proposed target detection algorithm’s capability was tested and validated with through-the-wall radar images of the wooden and metallic targets of different shapes and sizes. It was found that based on the statistics of the through-the-wall radar image of the target, the fitness function provides an optimal threshold value while maintaining the user-defined constraints of accuracy and false alarm. The performance of algorithms were evaluated by computing two performance measures, true positive pixel and false positive pixel and compared existing thresholding methods like mean based thresholding, maximum entropy, based thresholding, and otsu based thresholding techniques. The results exhibited that the proposed algorithm detects target pixels with better than 90% accuracy, which was our desired aim of the proposed target detection methodology and also achieved nearly less than 5% of false alarm. The good accuracy of the proposed algorithm shows that it can be implemented as a generalized tool.

In Chapter 5, a methodology to identify shape of target behind a wall has been presented. The developed methodology consists of through-the-wall image formation of the target, segmentation and shape identification using neural network. Instead of analyzing three dimensional image of target, we have focused on analyzing 2D through-the-wall image of target (horizontal cross range vs vertical cross range) to estimate target shape and its area because there is limitation in the range direction which depends upon the penetration depth and range resolution. If targets are metallic then no there will be no penetration of microwaves and so it is difficult to get depth information of the targets whereas if targets are of low dielectric then penetration is possible, but for knowing the depth, range resolution will act the major role which depends upon system parameters and we always have a tradeoff between range resolution, penetration and cross range resolution. Therefore, we have only focused to 2D C-scan image where we are getting information about shape of target. The two dimensional image of target was extracted from three dimensional image of target by selecting a plane at fixed target range bin which was selected by observing its range profile. For this purpose, C-scan data using indigenously developed SFCW radar in frequency range of 3.5GHz–5.5 GHz was collected for the different shapes of the wooden and metallic targets. From this C-scan data, 2D through-the-wall images of targets were formed. The foremost step while performing the task of shape recognition of stationary targets behind a wall was to first detect the target position, its approximate shape and size, and then, subsequent treatments were adapted on these detected targets with use of signal processing techniques for refining the shape of the recognized targets. Therefore, these radar images were segmented using statistics based segmentation technique to separate the target region. The detected target images did not corresponds to the actual shape and size of targets therefore this detected target image was further used to teach the artificial neural network for estimating actual shape of target. An effective training technique has been used to improve the effectiveness of the proposed algorithm. In order to make artificial neural network model orientation and size invariant a lot training data of 2D through-the-wall radar images of the target were required to train the artificial neural network to increase the detection accuracy of the artificial neural network model. The number of training data can be increased with the help of multiple scanning of various targets behind the wall but it requires a long time. Therefore to save time, C-scan data have been collected for the metallic and wooden target of different shapes and orientation to generate the 2D C-Scan through-the-wall radar image and then synthetic data of 2D C-scan through-the-wall radar image of different sizes of targets have been generated using morphological technique. Further, performance of trained artificial neural network has been verified through real independent data for its usefulness and practicality. The experimental results showed that the developed artificial neural network model has correctly identified shapes of real target samples irrespective to orientation of target in most of the cases.

6.2. Scope for future research work

In the present thesis, a study of through-the-wall radar images for detection and recognition of shape and size of the stationary targets behind wall has been presented. The following scope and possibilities based on the present thesis work are suggested for further extending and exploring the research in this area:

(i) In this thesis, imaging algorithms such as delay and sum beamforming, frequency-wavenumber and backprojection has been applied to check its effect with TWI data. Similarly, different imaging algorithms based on compressed sensing, and MIMO radars can also be investigated to check its effect with the TWI data.

(ii) Instead of using the Artificial Neural Network for target recognition, other types of the pattern recognition methods using other features, e. g., based on geometric, parametric models, textures can also be investigated.

(iii) Instead of using simple regular shapes of the targets for recognition purpose, complex shapes of the real targets can also be considered as extension of research in this area.

(iv) The building wall considered for development of target detection and identification technique through wall constructed with brick and cement plaster for example core: bricks and side: cement plaster. Similar technique could also be developed by considering wall constructed with the concrete and plasterboard for example core: concrete and side: plasterboard.