Chapter 7

Conclusions and future scope of work

7.1. Introduction

The goal of this thesis is to develop efficient defect detection techniques where defect detection accuracy is improved and operational simplification is achieved. The motivation is guided by the fact that the fabric defects are usually very small in comparison to the entire fabric image captured by image acquisition system. Therefore, high resolution images are required for fabric defect detection which demands faster algorithms to compensate their heavy processing cost. The algorithms and methods for detection of defects therefore face challenges due to (a) numerous categories of fabrics, (b) distinct composition of various fabric textures (c) similarity in shape between defects and background texture and (d) numerous shape, size and types of defects. The population of fabric defects may also vary dynamically as small changes in the weaving process may result in an entirely new class of fabric defects. Further, each of the detected defects needs to be classified into one of the several desired categories. Interclass similarity and intra-class diversity of fabric defects form major obstacles in their classification. Vagueness, incompleteness and ambiguity further pose difficulties in implementing an unique system.

It is difficult to tackle all the challenges by a single method and hope to achieve high detection success rate for a large quantity of samples from various fabric classes. Moreover, only a few existing defect detection methods [19,53] have real-time implementation. Among these methods, none could offer detection success rates over 90% in real environment. for noise-free testing images. Despite the significant progress in the last decade, the problem of fabric defect detection still remains a challenging one and requires further attention.

7.2. Summary of the work done and conclusions

An extensive review work of different existing defect detection techniques applied in the field of fabric defect detection so far has been carried out in Chapter 1. It is transpired that singular value decomposition technique has not been tried in detail in the defect detection scenario. Since the fabric images are of large dimensions, in order to evolve computationally efficient algorithms, it is also necessary to use modular sub-image based approach.

In Chapter- 2, a sub image based defect detection technique using image reconstruction scheme by singular value decomposition (SVD) method is proposed. Selection of region of interest (ROI) by adaptive partitioning is evolved to find the region of interest (i.e. defective region) in the fabric image. It has been established that the significant singular numbers representing the interlaced grating structure of fabric decreases drastically with the decrement in size of sub image. Application of sub image based singular value decomposition method along with the determination of ROI by adaptive partitioning reduces the computational cost by great extent. However elimination of the dominant singular values, representing fabric background may not be able to isolate the fabric defect completely in some cases of fabric class and particularly for very small fabric defects. Thus a simple threshold operation is carried out to output the fabric defects.

Though the method proposed in Chapter-2 reduces the computational cost, yet it does not offer an efficient way of memory management the process still works with large number of coefficient. Thus another defect detection technique is proposed in Chapter 3 by developing a reduced coefficient modified fabric space. The optimum dimension of the fabric space for a fabric class is evolved by particle swarm optimization technique. A very high rate of defect detection with an optimized and minimum number of features for wide variety of fabric defects on varieties of fabric classes is obtained by using this method. This method not only optimizes the features representing fabric defects for better memory management, but also offers more computational efficiency than the existing eigen filter based methods for fabric defect detection. The rigorous training process does not become a barrier for its use in real time, as the training is done off-line.

As the performance of any automatic defect detecion technique is dependent on the fabric class, it is necessary to have knowledge of fabric class which can be expressed by a set of Haralick parameters. The Haralick parameters are expressed by general features of textures and are derived from gray level co-occurrence matrix (GLCM). It is noted that all parameters may not be essential for defining fabric class. Therefore a reduced set of Haralick parameters giving maximum classification accuracy for determining a fabric class, denoted as optimum Haralick parameters, are derived by using the rough set based approach in Chapter 4. It has been shown that the approach enhances the separability index i.e., the ability to group identical classes together. However, the selection of optimum Haralick parameters for the classification of a fabric classes depends on the nature of fabric class.

Once the fabric class is derived in terms of optimum Haralick parameter, the ability of artificial neural networks to describe complex decision regions and robustness and simplicity of morphological operations have been utilized to implement a novel neural network trained morphological method for the detection of defects in fabric in Chapter-5. The artificial neural network is used for the selection of suitable size of sliding window, size of structuring elements required for morphological opening based reconstruction operation, threshold value required for removal of interlaced grating structure of fabric. These values are used for detecting the fabric defect in its original shape and size. The proposed method is simple but shows promising result in detection of varieties fabric defects on variety of fabric samples.

Finally, the performance of defect detection in fabric is explored in frequency domain as an alternative to spatial domain operations. However, in contrast to usual 2D Fourier transform operation, the technique of defect detection as established in Chapter 6, is based on 3D Fourier transform method. In this case multiple 2D fabric images are used to generate a 3D fabric image by arranging them along fabric frames. A cylindrical band pass filter of proper outer radius is used to remove grating structure from the reconstructed fabric frames, from where the fabric defect is finally detected by suitable energy thresholding. The energy threshold value and outer radius of band pass cylindrical filter for a fabric class is determined by particle swarm optimization (PSO) technique. As the proposed method takes care of a numbers of fabric frames simultaneously, so a very fast defect detection is possible by this method.

All the methods proposed in different chapters are established by test results carried out on TILDA database. Since defect detection in fabric is carried out at constant illumination level, the effect of illumination on the method proposed is not considered. Satisfactory results for a wide variety of fabric defects on different fabric classes are obtained. However, there is no indication to establish that a particular type of method is superior than the other methods proposed.

7.3. Future scope of work

This thesis has illustrated few effective defect detection techniques for woven fabric. The scope of future work may be divided into immediate scope and long term scope. Short term or immediate objectives of research may be stated which may improve the performance of the defect detection techniques. The following points may give possible outlines of future work.

1. The techniques proposed in the thesis are applied on plain weave fabric samples. These works may further be extended for other fabric structures such as, ribbed or corded fabrics. It is interesting to know the results of the proposed methods when applied to twill, stain and other fabrics of coarse structures such as denim. These samples are not tried because no standard data base of these samples are available.
2. In the thesis all fabric images are gray scale images. It will be interesting to know how the techniques are applicable for fabrics woven with colored yarns.
3. It will be interesting to know how a defect detection technique behaves when applied to patterned fabrics. In this case two types of defects may arise; one due to the irregularities in pattern and other due to the defects in basic interlaced grating structure.
4. 3D Fourier transform techniques needs to be analyzed in more details to know the interrelation of other fabric parameters such as thickness, yarn spacing, wrinkles etc.
5. It is possible to study the performance of all reported fabric defect detection techniques for a common recognized fabric data base such as TILDA. However, the methods may be tried using general texture databases.

6. Finally, the future work may be undertaken to implement the technique in the real time fabric defect detection system attached to a weaving loom under standardized illumination and image acquisition system.

Long term extension of the work done may lead to many fundamental question regarding the attempts are made to recognize and classify a defect. Perhaps, while travelling through the webs of patterns with or without defects in woven fabric, one may inclined to accept that there can be at least two varieties of realities. One may go a step further beyond the process of hardware recognition and classification of defects by computer to the identification of defects by human visual system. The problem however, then turns beyond the realm of technological realities.

Some elaboration may be in order when we scrutinize the actions of present day human detection of defects. The process revolves round the mind-body problem centered round the perception, sensations, understanding, consciousness and actions. Those are related to the mental abilities and generally are beyond the scope of hardware of technologies. There is a central issue involved regarding the process involved in which brain - the material object of our body can evoke signals in our mind, which in turn may control many of our actions or inactions for detecting and perhaps eliminating a defect. This may inspire another useful curiosity in intelligent defect detection, which may go beyond the *hard* scientific or technological issues to the areas of reasoning and consciousness. In the present dissertation, we have not touched upon the issues of realities of mind-body problem, but have explored the realities of second kind; those are much discussed and investigated under the realm of technology. We attempt to realize machines or more so the methodologies those can work and can detect deviation from regularities, in a limited sense of practical world.

Incidentally, the presently practiced manual system of defect detection is one aspect of coordination between visual perception, intelligence and muscle action – an action of first kind. However, one should be conscious and accept that the two kinds of realities are interdependent - which means that there can be a correlation between the two. Perhaps a day is not far off when these questions would be addressed in the language of science and translated in the domain of technology.

As an epilogue, it must be acknowledged that many issues in this work have not answered or addressed or conspicuously absent. We may quote from the aphoristic book "Tractatus Logico-Philosophius" by L. Wittgenstein, "*what we cannot talk about we must pass over in silence.*"