

# **1. INTRODUCTION**

## **1.1. OVERVIEW TO THE RESEARCH TOPIC**

Textile and garment industries are one of the fastest growing and competitive markets worldwide and form a major part of production, manufacturing, employment and business operations in many developing countries. Currently, the total global textile export is worth around \$294 billion according to the survey conducted in 2011 (<http://www.fashionunited.com>). The textile industry internationally has experienced dramatic technological changes during the last few decades. The changes have increased, both yield and quality of fabrics, apart from reducing expenses and labor cost. The 21<sup>st</sup> century is envisaging intense competition in textile industry and as a consequence, majority of the companies are paying more attention on improving their quality.

According to the International Organization for Standardization (ISO 8402) (Oodan, 1998), quality is defined as the totality of features and characteristics of a product or service that bears on its abilities to satisfy stated or implied needs. Companies and industries, therefore, requires a specification that describes terms that can be used to identify a product's functional, durability and appearance requirements to meet international standards. These specification can also include sample size, sample frequency and acceptance criteria for certain quality characteristics.

Further, in order to cope with this competition, manufacturers are also implementing production processes that help them to increase production efficiency both in terms of usable finished product and achieving faster production speeds. The manufacturers and textile businesses also want to reduce costs that are linked with both material and waste and also to improve product quality. Higher remuneration has become the important cause for all manufacturers to pay attention on developing technology that reduce operation

cost and increase product quality. This is especially more important in textile materials, as defective fabrics reduce its price significantly. Among the various failures faced by garment industries, fabric faults constitute more than 85% (Sengottuvelan *et al.*, 2008). It is considered as an serious issue, as failure in defect detection may result in warranty claims liability, recalled orders along with loss of customers, all of which affect the growth of the company extremely.

According to Srinivasan *et al.* (1992), the price of defective fabrics (second quality) decreases by around 45% to 65% of that of first-quality fabric. Second quality fabrics are fabrics that may contain a few major defects and/or several minor structural or surface defects (Chan and Pang, 2000). Thus, in order to gain more profit by producing and selling more first quality fabric, it is essential for textile factories to install advanced machines that can eliminate fabric defects. However, changes in the production processes may lead to introduction of more defects.

Inspection of fabrics forms an important aspect of quality control of automated production process and is needed to scrutinize the quality of fabric. Inspection is an activity that involves measuring, examining, testing and gauging the characteristics of fabric and comparing the results with the specification to establish whether conformity has been achieved for each characteristic. One another important aspect of inspection is defect detection, which is the act of identifying abnormalities that spoils the aesthetics (clean and uniform appearance of the fabrics) and affects inspection parameters like dimensional stability.

Presently, in most of the industries, this inspection process is performed manually by human operators who perform a visual examination to identify defects in fabrics. Often, these operators are without adequate training and in majority, miss defects due to fatigue and lack of time. In order to achieve maximum benefits from the inspection process, the information captured from

inspection must have high degree of accuracy and also the data regarding quality and inspection must always be updated continuously such that the process control can be quickly adjusted to maintain the optimum quality. Both of these requirements are not highly met by manual process, which apart from being error-prone, can also be exhaustive and neglectful.

An expert in human visual inspection can only catch around 60% to 75% of the significant defects (Mak *et al.*, 2012). Also, the detection results are usually not accurate. According to Sari-Sarraf and Goddard (1999) and Kumar (2003), even the most highly trained and qualified inspectors can identify only about 70% of the defects. Furthermore, textile industries are facing increasing pressure to be more efficient and competitive by reducing costs. Therefore, it is highly desirable to automate the process of fabric inspection that can be used to improve the quality of fabrics and garments.

This research work focuses on the design and development of such an automatic defect detection system that can be used as a tool during fabric inspection. In particular, the study focuses on patterned fabrics, which consists of a repetitive design or decorative designs. The wide usage of patterned fabrics has increased the demand in the quantum of production, which to a great extent, is fulfilled by the mechanization process of textile manufacturing. The usage of power looms during fabric production has enabled textile industries to design quality fabrics in relatively short time. One important process in fabric automation is quality control, which play a predominant role in the maintenance of standards and is mainly accountable for assessing and identifying whether or not the manufactured fabric is upto the expectation of buyer's requirement. As modern manufacturing processes of these fabrics are not perfect, defective patterns are frequently found on these items.

Defect detection on patterned fabric is a challenging task due to the appearance of a repetitive pattern on fabric. Nowadays, automatic fabric defect detection is mainly for non-patterned fabrics and these methods can be broadly

grouped as statistical approach, spectral (Gabor) approach, model-based approach, learning approach and structural approach (Ngan *et al.*, 2011). The number of methods, on the other hand, for patterned fabrics, is sparse. In spite of few researches concentrating on patterned fabrics, in the commercial world, the market value of patterned fabrics is much higher than that of non-patterned fabrics.

The methods proposed for patterned fabrics, in general, can be grouped as motif (decorative image or design repeated on a fabric to form a pattern) or non-motif based techniques. Examples of such techniques include subtraction, color averaging method and wavelets. However, these techniques apart from being computationally complex also degrade in the presence of noise or when the size of defect is smaller than the size of one repetitive pattern. Thus, the field of automatic defect detection on patterned fabric is still an active research area, where techniques that provide reliable, objective and stable performance are still desirable. Researchers in this field are actively pursuing new and innovative methods to achieve acceptable detection rate for a variety of defects.

This research work focuses on proposing both motif and non-motif based techniques that use amalgamation of image processing and machine learning techniques to detect defects from 2-dimensional patterned fabrics. This chapter provides the introductory materials related to the topic along with research objectives.

## **1.2. FABRICS AND PATTERNED FABRICS**

Fabrics, defined as textile materials produced through weaving or knitting, play a vital role in human life from prehistoric times and its usage can be traced back over 8500 years. Its varied importance in daily life can be understood from its wide usage in clothing, furnishing, symbolic communication and commerce. It is used for protecting, cleaning, holding things and tying things together. It is a flexible woven material consisting of a network of natural or artificial fibers often referred to as thread or yarn. Yarn is

produced by spinning raw fibers from materials like wool, cotton or flax (<http://www.textilemuseum.org/PDFs/TextileTerms.pdf>). Fabrics are formed by weaving, crocheting, knitting, pressing or knotting fibers together (felt).

Fabrics are categorized according to the raw materials used to manufacture, which can be natural or synthetic (artificial). In early days (before 1930's) all fabrics were totally natural and were manufactured using weaving and knitting processes. Examples of this type of fabrics include wool, cotton, linen and silk. Some example natural fabric images are shown in Figure 1.1.



**Figure 1.1: Natural Fabrics**

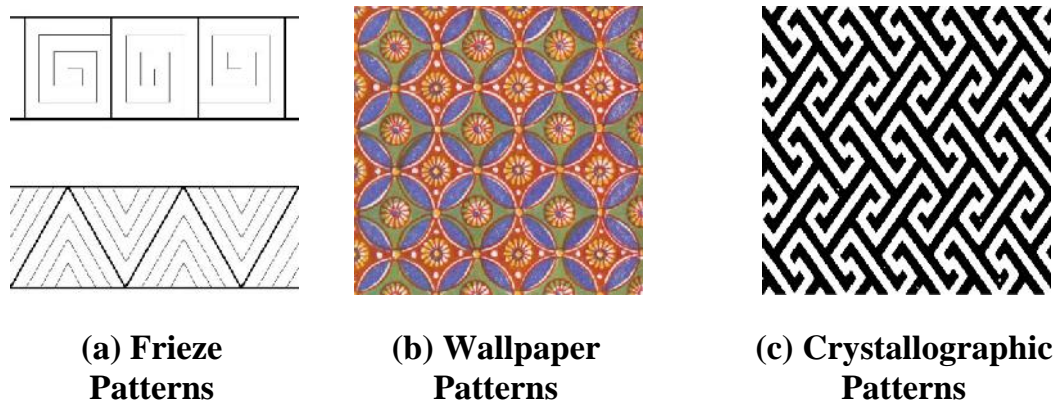
During the last 50 years, the usage of synthetic fabrics came into existence having different array of mixtures and blends. They are man-made instead of nature fibers. Some examples of synthetic fabrics include polyester, acrylic, nylon, rayon, acetate, spandex, lastex and kevlar. These fabrics have made a tremendous impact on garment industries and are differentiated mainly by hand (the way fabric feels) and drape. Figure 1.2 shows some synthetic fabrics that are available currently in the market.



**Figure 1.2: Synthetic Fabrics**

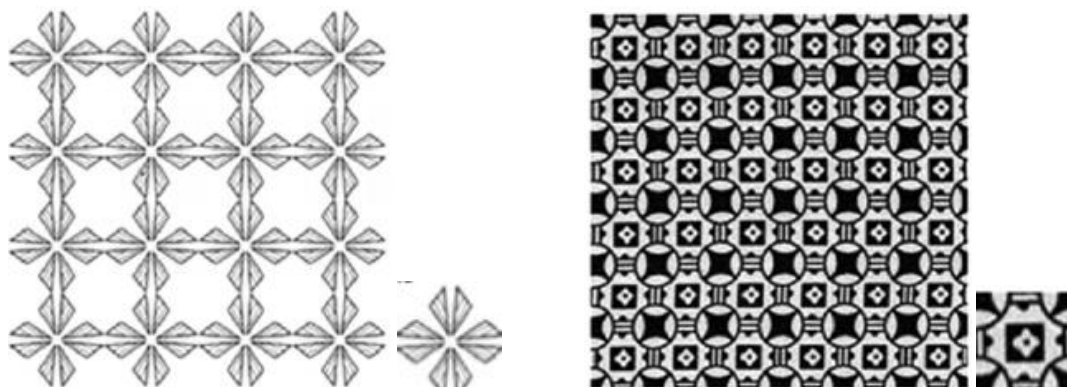
Irrespective of the category, the fabrics belong to two main groups, namely, patterned and non-patterned fabrics (Behravan *et al.*, 2011). They are distinguished from each other by the appearance of repetitive unit on the fabric. Non-patterned fabrics have simple and homogenous repetitive units and generally have directional texture without special patterns. Patterned fabrics have significant repetitive patterns including artistic or decorative designs. The repetitive unit of non-patterned fabric is the directional texture without special pattern. On the other hand, the patterned fabric is defined to have significant repetitive patterns in the original design.

Patterned fabrics have many categories and sub-categories among them. For example, a pattern can be a flower or graphic logo on the fabric. Figure 1.3 illustrates the classification of fabrics. The repetitive unit can range from the simplest character box, dots, to the most complicated multiple flowers, animals or designed patterns. These kinds of fabrics are commonly found in many daily items like wallpapers (Castro *et al.*, 2005), ceramic tiles (Smith and Stamp, 2000), fabrics (Tao *et al.*, 1997; Sari-Sarraf and Goddard, 1999), painting, pavement, architecture, netting, ropes, chains, patterned metals, heated windows and other safety critical materials (Ngan *et al.*, 2007).



**Figure 1.3: Types of Patterned Fabrics**

It is composed and constructed by a fundamental unit called lattice (2D grid) that generates corresponding wallpaper group patterns by replication with certain isometrics like translations, rotations and reflections. Usually, a patterned texture is synthesized by applying proper symmetry rules ([http://en.wikipedia.org/wiki/Wallpaper\\_group](http://en.wikipedia.org/wiki/Wallpaper_group)) of that lattice. A lattice can be decomposed into a finer component called motif, which can regenerate the entire lattice by applying symmetry rules. Figure 1.4 shows some examples of patterned fabric and its lattices.



**Figure 1.4: Patterned Fabric and its Lattices**

(Source : Ngan *et al.*, 2008)

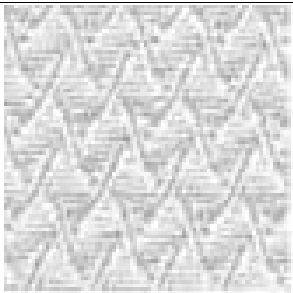



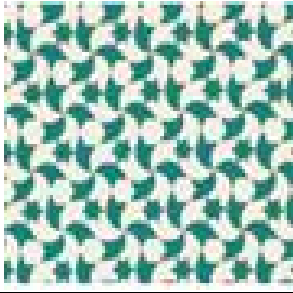



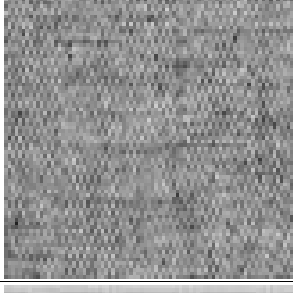

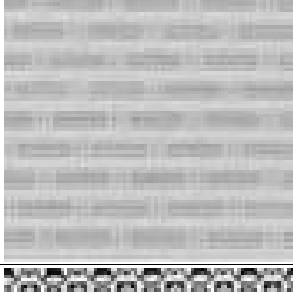



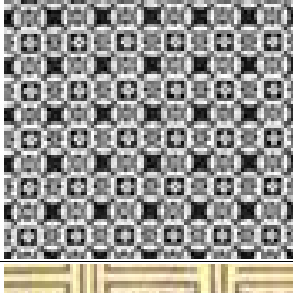
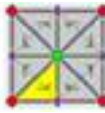


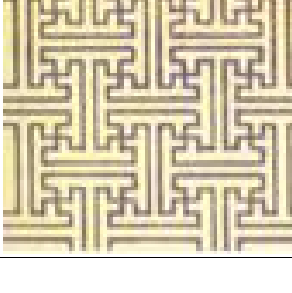



The designs in the patterned fabrics can be categorized into any one of the three groups given below.


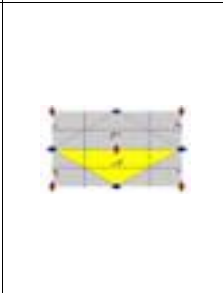


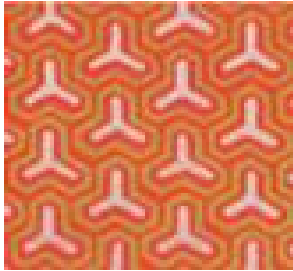
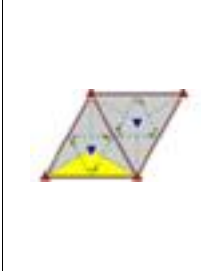



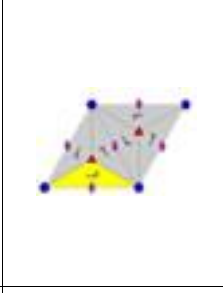



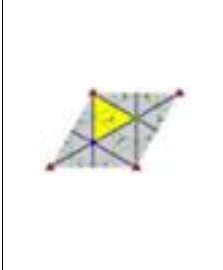



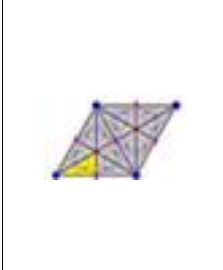







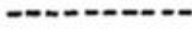

- 1D pattern belonging to frieze pattern groups (Figure 1.3a)
- 2D patterns belonging to wallpaper pattern groups (Figure 1.3b)
- 3D patterns belonging to crystallographic pattern groups (Figure 1.3c).

This study considers only 2D patterns belonging to wallpaper patterns. A wallpaper group (or plane symmetry group or plane crystallographic group) is a mathematical classification of a two-dimensional repetitive pattern, based on the symmetries in the pattern. Such patterns occur frequently in architecture and decorative art ([http://en.wikipedia.org/wiki/Wallpaper\\_group](http://en.wikipedia.org/wiki/Wallpaper_group)). Though patterned fabric designs being produced by modern textile industries are plenty, all patterned fabrics can be classified into only 17 wallpaper groups that are composed of lattices of rectangular, parallelogram, square, hexagonal or rhombic shape (Asha *et al.*, 2011).

The 17 wallpaper groups differentiated by symmetry and shape is shown in Figure 1.5. They are p1, p2, pm, pg, cm, pmm, pmg, pgg, cmm, p4, p4m, p4g, p3, p3m1, p31m, p6 and p6m. Here, letter p denotes a primitive cell (which is a minimal area duplicated by lattice translations), c is a face-centered cell. The integer that follows p or c indicates the highest order of rotational symmetry that is 1-fold, 2-fold, 3-fold, 4-fold or 6-fold. Symbol m refers to reflection symmetry while symbol g refers to glide-reflection symmetry. A glide-reflection symmetry means that a pattern can reflect in one line and translate along a certain distance, in order to get exactly the same pattern. As mentioned earlier, every group here is defined using a fundamental unit called lattice along with its finer component called motif. The lattice (2D grid) generates corresponding wallpaper group patterns by replication with certain isometrics like rotations, translations and reflections.

Pattern Type	Image	Ideal Lattice	Lattice	Motif
Rectangle ppm				
Rectangle pm				
Rectangle pg				
Rectangle pmg				
Rectangle cmm				
Square p4				

Pattern Type	Image	Ideal Lattice	Lattice	Motif
Parallelogram p2				
Parallelogram p3				
Parallelogram p1				
Isosceles Triangle cm				
Isosceles Triangle p4m				
Isosceles Triangle p4g				

Pattern Type	Image	Ideal Lattice	Lattice	Motif
Isosceles Triangle pgg				
Isosceles Triangle p31m				
Isosceles Triangle p6				
Equilateral Triangle p3m1				
Half-Isosceles Triangle p6m				
Centers of Rotation:		 2-fold  3-fold  4-fold  6-fold	 axis of reflection  axis of glide-reflection  outline of lattice unit	

**Figure 1.5: 17 Wallpaper Groups**  
 (Source: Ngan *et al.*, 2011)

Strictly speaking, p1 defines a texture with just one lattice repeating itself over the complete image such as plain and twill fabrics. From the rest of 16 wallpaper groups, pmm, p2 and p4m are called major wallpaper groups as other groups can be transformed into these three major groups through geometric transformation (Ngan *et al.*, 2010).

### **1.3. FABRIC INSPECTION SYSTEM**

Product or fabric inspection is an important aspect in modern manufacturing industries such as in case of electronics, automotive and medical industries. This process is broadly defined as the process of determining if a product deviates from a given set of specifications (Newman and Jain, 1995). Mainly, fabric defect detection has two distinct possibilities (Kumar, 2008). The first one is the product or end (offline) inspection in which the manufactured fabric has to be inspected through fabric inspection machines (Anagnostopoulos *et al.*, 2001, 2002). The second possibility is the process inspection (online) in which the weaving process (or its parameters) can be constantly monitored for the occurrence of defects. This section presents a brief introduction to both these types of inspection processes.

#### **1.3.1. Need for Fabric Defect Detection Systems**

Fabric defect detection is performed prior manufacturing so as to avoid rejects and unexpected loss. There are two objectives in the inspection process.

1. It sorts out good products from the products that have defects, before the products are shipped to the customers.
2. It regulates the manufacturing process by providing information to diagnose the status of the process. If needed, the correction can be made in order to prevent further loss.

Fabric inspection determines fabric quality by focusing mainly on detecting or identifying fabric faults. There are several advantages provided by fabric defect detection process. Some of them include the following.

- (i) Ensure high quality of finished garment
- (ii) Improve efficiency of production
- (iii) Ensure timely deliveries
- (iv) Reduce rejections

Defect detection on patterned textures belonging to wallpaper groups other than p1 group is more complicated than that in textures belonging to p1 group due to complexity in the design, existence of numerous categories of patterns and similarity between the defect and background (Ngan and Pang, 2009).

The defects on patterned fabrics can occur during the production processes such as weaving of fabric, injection molding of ceramic and pulling clay for porcelain. There can be many types of defects on a patterned texture. For example, there are over 90 defects existing in fabric production. This study focuses in designing a defect detection method for the 2D pattern texture. A defect on a 2D patterned texture would possess a grey-level intensity change and occupy a region which is different to the defect-free pattern in patterned texture. Upon wallpaper group concept, a defect on a lattice would make a substantial and visual difference with a defect-free lattice.

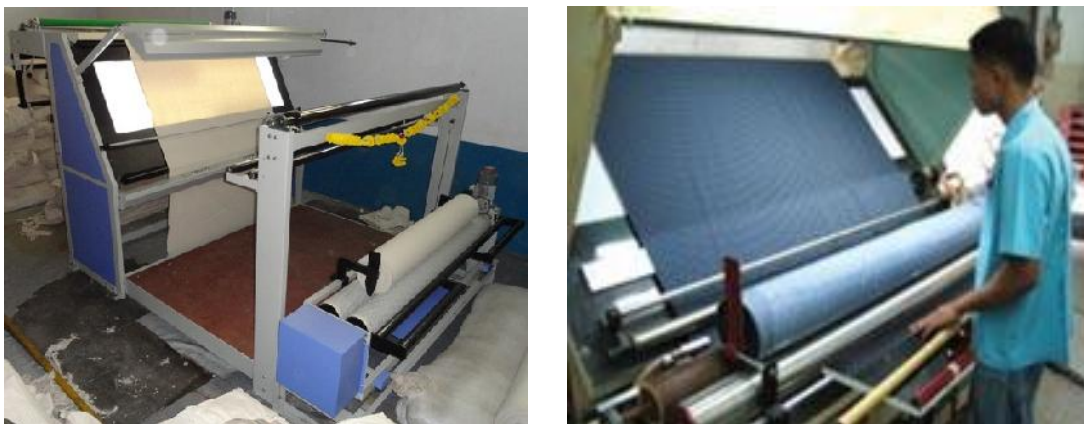
Therefore, a successful defect detection method should be able to detect the defect out from an input patterned texture or lattice. Moreover, from an industrial point of view, need for fabric defect detection stems from the need of quality control in manufacturing. From consumer point of view need arise due to the increased awareness and pressure for quality service. From business point of view, need arises from its desire to produce highest quality goods in shortest period of time possible.

As the presence of defects in fabrics cause rejection of fabric which results in fabric wastage and monetary loss, it is always desirable to detect these defects as early as possible. Therefore, in order to lower the cost of the inspection process and to increase the competitive advantage of the products, it is highly desirable to automate the inspection process.

### 1.3.2. Visual (Traditional) Fabric Inspection

Fabrics, generally, are available in a web form (continuous rolls) where defects to be detected by inspection are numerous and present complex appearance (Conci and Proença, 2000b). As a result, industrial web inspection (Kumar and Pang, 2002a) has extremely high requirements and is most challenging as compared to other inspection problems. As mentioned earlier, traditionally, this procedure is performed by well-trained human inspectors (experts) (Sengottuvelan *et al.*, 2008; Paladini, 2000; Nishimatsu *et al.*, 1995) and the procedure used by them varies from mill to mill (Baykut *et al.*, 1998).

Most mills have power driven inspection machines where the manufactured fabric rolls are removed from the weaving machines and unrolled on an inspection table (under adequate light) at a relatively higher speed of eight to twenty meters per minute (Kumar, 2008; Baykut *et al.*, 2000; Kumar and Pang, 2002b; zdemir and Erçil, 1996), which is inspected by the expert (Figure 1.6).



**Figure 1.6 : Visual (Traditional) Fabric Inspection**  
(Source : <http://www.indiantextilejournal.com>)

When the expert identifies a defect, the machine is stopped and details regarding the defect along with its location are noted, before the machine is restarted. Finally, for each inspected fabric roll, the number of defects per meter length is calculated and the fabric is classified as defect free or secondary fabric. When the number of defects is very high or if the defect is repeated in many fabric rolls, the expert warns production department and appropriate correction actions are taken.

However, the process to identify fabric defects has some serious drawbacks. Some of these drawbacks are listed below.

1. The traditional visual inspection relies completely on human eye and even with the best-designed man-machine interface, the probability of human error cannot be reduced to zero in practice (Sylla, and Drury, 1995).
2. The visual inspection has worked well for many years in part because the amount of data has been small and manageable (Anstey *et al.*, 2005).
3. Human experts are difficult to find or retain in an industry. Moreover, training non-experts is time consuming and costly and even human experts are slow when compared with machines.
4. Human inspectors fatigue over time (get tired quickly), whose concentration power decreases after 20-30 minutes. After this time period, the operator inevitably misses small defects and sometimes even large ones with the number of meters of the inspected fabric.
5. Human experts have to deal with an extensive variety of defects and their inspection is unreliable when the fabric width is more than two meters and when the production speed is very high.
6. With the modern machines, the production speeds and consequently productivity are faster than ever. The experiments show that the error

rate begins to rise rapidly as information output approaches about 8 bits/s (Ayes, 1987).

Therefore, the traditional visual inspection method has no ability to cope with today's requirement and hence automated inspection systems for fabric fault detection are highly preferable.

### **1.3.3. Automated Fabric Inspection**

With the advent of global sourcing, the need for effective quality measurements is more important than ever and there is an increased need for a consistent and comprehensive way to establish the quality of goods, for which automated fabric inspection is an excellent solution (Guruprasad and Behera, 2009).

Automatic inspection systems are designed to increase the accuracy, speed and consistency of defect detection in fabrics, which can consequently reduce labour costs, improve product quality and increase manufacturing efficiency (Su *et al.*, 2010; Malek *et al.*, 2011a, 2011b; Henry *et al.*, 2011). From its introduction in 1997 at ITMA in Hannover (Schick Tanz, 1996) (based on a laser scan system), there have been several key developments in automated visual inspection technique for fabric defects where new approaches such as an ultrasonic imaging system (Chien *et al.*, 1999) and laser-optical systems (Allgood *et al.*, 2000; Shao and Kuze, 1990) have been proposed. But, the main common alternative to human visual defect detection is the use of a computer vision system to detect differences between images acquired by a camera (Kim *et al.*, 2005). The operation of an automated visual inspection system can be broken down into a sequence of processing stages, such as, image acquisition, feature extraction, comparison and decision. It is important to note that the success of an automatic inspection system relies on the approach used in each of these steps.

The central part of automatic inspection systems is the image processing operations and analysis techniques used. The standard defect detection system consists of five components, as shown in Figure 1.7. The five components are

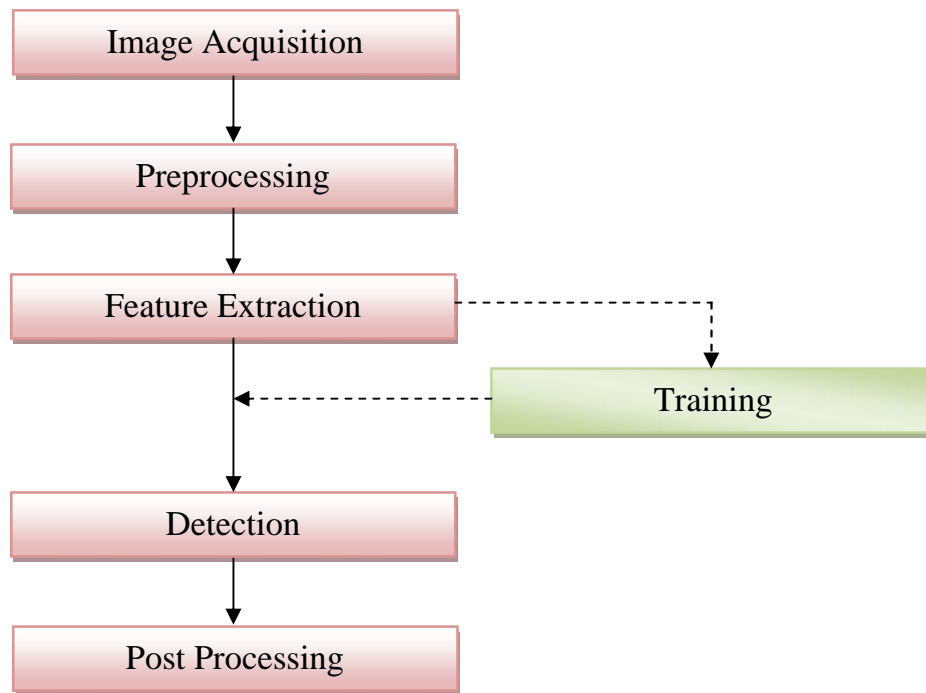
- (i) Sensing (Image Acquisition)
- (ii) Preprocessing
- (iii) Feature Extraction
- (iv) Detection Scheme
- (v) Post Processing.

- **Image Acquisition**

Sensing usually means image acquisition in a defect detection scheme (Ruda *et al.*, 2000). Different instruments such as line-scan camera (Karayiannis *et al.*, 1999; Stojanovic *et al.*, 2001; Sandy *et al.*, 1995), Charge Coupled Device (CCD) camera (Hoffer *et al.*, 1996; Anagnostopoulos *et al.*, 2001), webcam (Rohrmus, 2000) could be chosen as the sensor for an automated defect detection system. These devices are used to digitize the fabric into quantized images. The common requirement of acquired images is vibration-free (Tsai and Huang, 2003) and even illuminations for good quality images. Both on-loom or off-loom fabric needs to be moving steadily in motion during inspection.

- **Preprocessing**

There are several types of errors due to sensing. First, quantization errors are commonly introduced to an image during its digitization. Second, noise, such as background noise (Mak and Pang, 2008) or Gaussian noise (Qui and Sun, 2006), is usually found in the input image due to wrinkles or uneven illumination of lighting. Third, alignment and distortion (Sandy *et al.*, 1995; Ngan *et al.*, 2005; Zeng and Hirata, 2002), are two other errors which usually occur in the acquired images.



**Figure 1.7: Components of Automatic Fabric Defect Detection System**

Preprocessing techniques consists of methods that can be used to solve these degradations. The images captured in the first step are smoothed, so that the resulting images are more suitable for the subsequent processing steps. Usually the purpose of this step is to eliminate illumination non-uniformity, remove background noise, increase the contrast between defects and backgrounds, and correct geometric distortions introduced by the image-capture system, etc. Filtering techniques such as median filter, wavelet transform, are sometimes applied to remove the noise in the acquired images. Histogram equalization is a widely used enhancement method to adjust the contrast of images.

- **Feature Extraction**

In the third step, a set of known features are extracted from the image to characterize a specific application domain. The purpose is to obtain good classification results based on such features. In general, features can be evaluated on two aspects: good classification ability and low computational complexity. Those which can achieve good classification results with low

computational efforts are good features. However, in most cases, it is very difficult to satisfy both aspects. Therefore, extensive research work is still required to find a good tradeoff between these two aspects. Usually this step is the core of the whole inspection software.

Feature extraction is used to obtain for distinguished features that are invariant to unrelated transformation of the input (Ruda *et al.*, 2000). In general, most researchers want to pick up the features invariant to translation, rotation and scale. Features are usually viewed as two groups, structural and statistical, in this step. Examples of such approaches include autocorrelation, histogram, co-occurrence matrix, Fourier transform, wavelet transform and structural approach. Feature extraction can be processed by selecting the whole input image or dividing the input image into certain amount of appropriate size of windows (Yang *et al.*, 2002a). After feature extraction, the automated system should perform feature calculation for different detection approaches.

- **Training**

For supervised learning, there exists an intermediate stage called a training stage (or learning stage), between feature extraction and detection. Certain amount of defect-free images will be collected and used as reference images for training. Depending on different feature extraction methods, the training will be fine adjusted to collect the optimum parameters and threshold values in detection. Some researchers like to use neural network classifiers to train defect and non-defect fabrics (Tilocca, 2002; Rohrmus, 2000; Egmont-Petersen *et al.*, 2002). On the other hand, Zhang and Bresee (1995) showed a systematic diagram for training setup in comparison of fabric defect detection between gray level statistical approach and morphological approach. Bodnarova *et al.* (2000) also outlined his training stage for optimal Gabor filters for textile flaw detection.

- **Detection**

Detection scheme, or called testing stage, is a stage to determine if an input sample is defective or not. This step aims at determining the presence of the defects out of the background. So, detection part can be considered as a segmentation process in image analysis. Thresholding will be the most useful and convenient way to achieve the goal. The output of thresholding will be a binary image that is helpful to show the defective information. Apart from thresholding, there are many other detection schemes such as discrimination rules in statistical modeling, acceptance error in structural approach and feedback loop decisions in neural networks.

- **Post-processing**

The last stage of supervised defect detection is post-processing. After the step of thresholding in detection, there are usually noises found in the thresholded images at the stage of detection. The noise is usually discovered as speckle-like noise, white impulse noise or residual noise after subtraction. This is because the underlying defects information can be further employed in defect classification. Spatial and morphological filters, Gaussian low pass filter, median filter are common methods for reducing noise levels in the thresholded image.

The advantages obtained through automatic fabric defect system are numerous and some of them are listed below.

1. They reduce false acceptance and false rejection rates and hence, the results are reliable and reproducible.
2. The systems are robust and flexible and adapt automatically to achieve consistently high performance despite irregularities in illumination, or background conditions and accommodate uncertainties like angles and positions.
3. They are fast and cost efficient.

4. These systems are simple to operate, maintain and implement.
5. Increases the efficiency of production and quality of product.

#### 1.4. MOTIVATION

An important step of quality control in textile industry is defect detection in the manufactured fabrics and is a popular subtopic in automation of inspection process. As mentioned earlier, the fabric defect detection can be performed either using visual inspection by a human expert or automatically. Table 1.1 presents the comparison between human visual inspection and automated inspection (Meier, 1996; Islam *et al.*, 2008).

**TABLE 1.1**  
**VISUAL INSPECTION AND AUTOMATED INSPECTION**

<b>Inspection Type</b>	<b>Visual</b>	<b>Automated</b>
Fabric Types	100%	70%
Defect Detection Rate	70%	80%+
Reproducibility	50%	90%+
Objective Defect Judgment	50%	100%
Statistics Ability	0%	95%+
Inspection Speed	30 m/min	120 m/min
Response Type	50%	80%
Information Content	50%	90%+
Information Exchange	20%	90%+

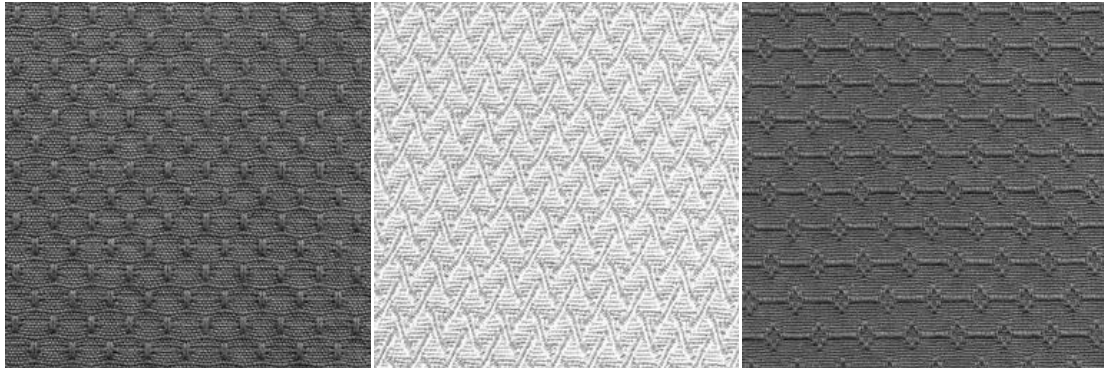
The table clearly shows that the automated systems provide more advantages during fabric defect detection and hence is considered in this research. It is a complex task and researchers have been working for several years to implement algorithms that can duplicate the excellent ability of human brain to recognize defects in fabrics. Advanced information technology and

demand for high quality, has forced academicians and researchers alike to search for different defect identification methods that are economical, fast, safe and accurate.

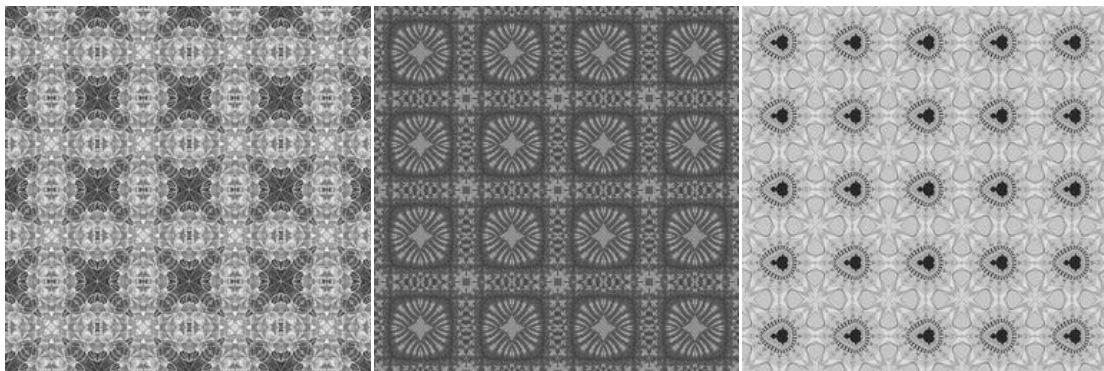
Until recently, machine vision was applied almost exclusively to the inspection of engineering components. However, with the various challenges faced by automatic fabric inspection, developing practical, consistent and reasonably commercial system using image processing and machine vision technology is taking its stride now.

With the increasing popularity of patterned fabrics, defect detection has become a focus area of research and is considered challenging because of the following reasons.

- Many fabric defects are very small and indistinguishable, which are very difficult to detect by monitoring the changes in intensity. This increases the misdetection rates of the system.
- Existing automatic fabric detection systems do not focus on patterned fabric defects and search for improving or optimizing existing methods or designing new and novel methods, is still an ongoing research problem.
- The pattern (repetitive unit) complexity of patterned fabric is much more sophisticated than that of non-patterned fabric. Normal defect detection methods on non-patterned fabric are not applicable on patterned fabric.
- The task is further complicated by the fact that the categories of patterned texture are numerous. For example, consider Figure 1.8 which consists of simple type of patterned fabric samples, while Figure 1.9 shows examples of fabrics having complicated design.

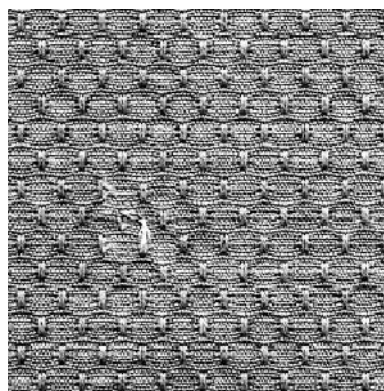


**Figure 1.8 : Simple Patterned Fabric Samples**



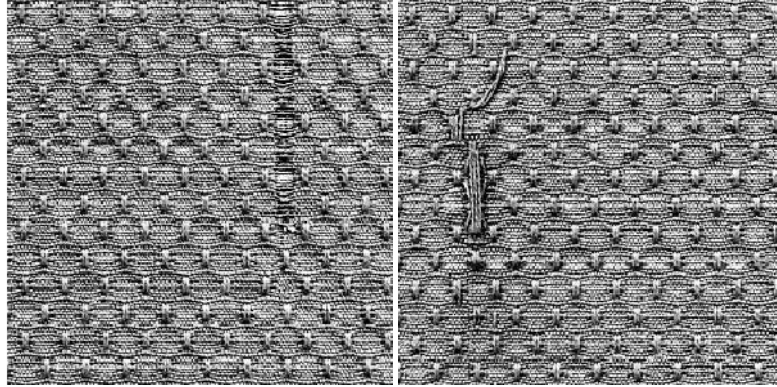
**Figure 1.9 : Complex Patterned Fabric Samples**

- The similarity in shape of defects and background texture is another difficulty faced by automatic patterned fabric defect detection system. For example, consider Figure 1.10, which shows a defect sample in the dot-patterned fabric that is similar to the repetitive unit of the dot-patterned fabric.



**Figure 1.10 : Patterned Fabric with Defect Similar to Pattern**

- Further, the close intensity levels between defects and background texture (Example in Figure 1.11) also poses serious challenges during defect detection.



**Figure 1.11 : Patterned Fabrics with Defects and Background with Similar Intensity Levels**

As a solution to the above issues, the textile and garment industry has acknowledged the advantages obtained while using computers to automate the process of fabric defect detection. Automated Defect Detection (ADD) systems use a set of pre-defined rules to judge if a fabric is defective or not. They provide several advantages over manual systems that include gains in productivity and increased efficiency during quality control. Computer vision-based automatic detection of patterned fabric defects is one of the difficult tasks (Bu *et al.*, 2009) and the solutions proposed so far can be categorized into two groups, motif-based and non-motif based algorithms. Non-motif-based approaches for fabric defect are traditional, while recent years are trying to use motif-based approaches as basic manipulation unit for fabric defect detection (Ngan *et al.*, 2009). This research considers both motif and non-motif based defect detection in patterned fabrics.

## **1.5. RESEARCH OBJECTIVES**

This research proposes techniques that aim to meet the above issues and has formulated the primary objective as below.

*“To find fast and reliable methods to detect and locate the defects in patterned fabric (textile) images using image processing and machine learning algorithms”*

To achieve this primary goal, several steps of the detection process are enhanced to meet the following specific goals.

- To develop preprocessing algorithm that improves the visual quality of the input patterned fabric so as to enhance the operation of defect detection.
- To design and develop automatic defect detection systems in patterned fabrics using non-motif methods (data fusion technique and wavelet transformation technique) to maximize the detection accuracy and reduce the error rate.
- To design and develop automatic defect detection systems in patterned fabrics that enhances the operations of motif-based methods to increase the performance of the defect detection process.
- To conduct performance evaluation for identifying the best method for detecting defects in patterned fabrics.

## **1.6. LAYOUT OF THE CHAPTERS**

The underlying objective of this research work is to develop an automatic fabric defect detection system to identify defects in patterned fabric. This chapter introduced the term fabric and patterned fabrics along with research objectives. Rest of the dissertation is organized as below.

In case of fabric defect detection, several researchers have addressed the problem of defect detection. A critical look at the various available literatures related to the present research work is given in **Chapter 2, Review of Literature**.

**Chapter 3, Methodology**, presents the research methodology and identifies the different steps of the defect identification system. The various methods and techniques used are briefly explained in this chapter.

The two main phases of the proposed defect detection system in patterned fabrics are preprocessing and defect detection. The method of enhancement used for preprocessing the patterned fabric images is discussed in **Chapter 4**.

In the second phase of the proposed system, two categories, motif and non-motif based techniques are considered. The design and implementation of these two techniques for defect detection in patterned fabrics are respectively presented in **Chapter 5 and Chapter 6**.

**Chapter 7, Results and Discussion**, tabulates and discusses the various results obtained while testing the proposed algorithms. The findings of the study are summarized along with future research directions in **Chapter 8, Summary and Conclusion**.

The work of several researchers are quoted and used as evidence to support the concepts explained in this dissertation. All such evidences used are listed in the **Bibliography** of the dissertation.

This chapter provided a brief introduction to fabrics with emphasis to patterned fabrics. The research objectives formulated were also outlined. To achieve the objectives outlined in this chapter, a review of the previous research work was studied and the scrutinized works are summarized in the next chapter, Review of Literature.