CHAPTER 3

RELATED CONTRIBUTIONS

According to the literature study performed it becomes evident that the detection should be simple, efficient and cost effective. This calls for proper understanding with the fabric features, defect types and underlying operational procedures.

3.1 FABRIC MANUFACTURING PROCESS

Normally textures are made with material strands. The material filaments can be made of characteristic component, for example, cotton or fleece; or a composite of various components, for example, fleece and nylon or polyester.

Fabric production is usually achieved in few basic steps. The first step is yarn production. It involves set of process that converts the raw fibers into yarn and threads. This requires spinning the fibers either by hand or by spinning wheel. Winding is the last step in spinning process. Winding
process involves transfer of spinning yarn from one package to another large package. In next step these individual threads are joined together by a process called weaving to form fabric. The woven fabric is discolored and full of impurities. Therefore it is treated with bleach and other chemicals to remove oils, wax and other impurities.
Dyeing and printing are crucial processes that are required for converting raw textile into finished fabric with desired appearance. Both as a wet processing technique used for coloration of fabric. Single color and grey fabric are often involved in Dyeing. Whereas multiple color and both

Whether a fabric is dyed or printed it can be easily distinguished by looking at the outline of the design. In printed fabric the design outline is sharp but does not penetrate to the other side. The following are some of the examples of fabrics.

![Figure 3.2. Various types of fabrics](image)

The plain weave fabric and knitted fabric are produced by weaving and knitting Dhivya & Devi et al (2017). The twill fabric is produced by either weaving or printing. Whereas the laces are produced by knitting and carpets are produced by any of weaving, printing or spinning. These processes itself have the tendency to cause various defects in fabrics. Locating or inspecting for defects requires detailed understanding on defects. Therefore
comprehensive categories of fabric defects are detailed in following section.

### 3.2 Classification of Fabric Defects

The defect is the common term in the garment industry. Since the defect in garment industry is identified as reject item. In India such defective garments are sold in subsidized cheap rates during a month. However in textile industries different four types of defects are identified and specified for better inspection process as listed in Table 3.1.

**Table 3.1 Types of Fabric Defects**

<table>
<thead>
<tr>
<th>Yarn Defects</th>
<th>Woven Defects</th>
<th>Knitted Defects</th>
<th>Dyeing Defects &amp; Finishing Defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broken Filaments</td>
<td>Broken Ends</td>
<td>Drop Stitches</td>
<td>Shade Variation</td>
</tr>
<tr>
<td>Knots</td>
<td>Float</td>
<td>Yarn Streaks</td>
<td>Crease Mark</td>
</tr>
<tr>
<td>Slub</td>
<td>Gout</td>
<td>Barriness</td>
<td>Pin Hole Damage</td>
</tr>
<tr>
<td>Fabric press off</td>
<td>Hole, Cut or Tear</td>
<td>Fabric press off</td>
<td>Dye Spots</td>
</tr>
<tr>
<td>Broken Ends</td>
<td>Oil Stain</td>
<td>Broken Ends</td>
<td>Wrong Slitting</td>
</tr>
<tr>
<td>Thick places</td>
<td>Slub</td>
<td>Spirality</td>
<td>Band Line</td>
</tr>
</tbody>
</table>
Any defect in a fabric or textile can be identified as a variation from the usual appearance *Gaidhani et al (2014)*. Texture defects can occur in non-textured areas or areas that locally differ from the background texture of the surface.

<table>
<thead>
<tr>
<th>Thin places</th>
<th>Missing end</th>
<th>Slub</th>
<th>Dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reed Mark</td>
<td>Broken Needle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colour Bleeding</td>
<td>Cracks or Holes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing Picks</td>
<td>Pin Hole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The figure 3.3 shows the rundown of ordinarily happening texture surrenders. The anticipated deformities ordinarily happen because of machine deficiencies, yarn issues, poor completing, and over the top extending. Gout is a knotty and unbalanced blame in a spun yarn of a texture...
which happens amid turning. Twist skim is a length of yarn that is unbound more than at least two progressive closures or singles out the twist heading. Downside is a weave contortion described by tight and slack places in a similar twist yarn. Hole or tear simply mean a small hole in the fabric. Dropped stitches are irregularities in yarning or stitching patterns. Press-off occurs accidentally with yarn breakage Gaidhani et al (2014). However enlisting all possible defects that can occur during manufacturing process is not realistic. Therefore any detection method that is applied should be capable enough to deal with unprecedented defects. Usually in garments industry the defects are classified into three types, they are; Critical defects, Major defects and Minor defects.

3.2.1 Critical Defects

If a defect is likely to results in hazardous conditions or unsafe for usage, then it is considered as critical defect. It is simply a huge deviation from delivery requirements and the product cannot be delivered to the customer at all. Usually the entire lot is rejected under the finding of even a single critical defect during inspection Shweta & Dhirendra et al (2015).
3.2.2 Major Defects

If a defect is likely to result in loss of reputation to textile industry if delivered to the customer then it is major defect. A major defect is also a significant deviation from delivery requirement and is usually not delivered to customers *Shweta & Dhirendra (2015) et al.* If such defects are failed to be noticed during inspection and accidentally delivered to customer then it may result in customer complaint or return.

3.2.3 Minor Defects

A minor imperfection is a slight deviation from the conveyance necessity and is probably not going to bring about client protestation or return. However a defect is a defect, if many manufactured products exhibit minor defects then it will definitely cause the product rating to go down and thus affects the business. A minor defect is often overlooked by the inspection process and still remains a huge challenge *Shweta & Dhirendra et al (2015).*

Consequently the size of the defect is a huge problem when it comes to defect detection. Minute defects are elusive and are hard to detect through expert inspection as well as for automatic detections. The methods which work with well-defined defect specification may be fooled by such
possibility *Minal et al (2017)*. Most of the computerized inspection techniques draw inspiration from pixel-wise defect labeling. However the surface inspection using fabric texture surface image defers significantly from general texture segmentation and classification, since the surface image and the defects are highly unstationary. The challenge is to segment the surface image into smaller regions to locate the defects. The challenge is to bring a defect within the segment if the defective region is split the defect detection results in poor performance. Moreover defects may not always falls within the trained defect sample class. Therefore to understand the Computer vision based texture defect detection application, the fundamental operations that serves as the core requirement is discussed in following section.

**3.3 Distinguished Characteristics of Texture Defect Detection**

The texture defect detection algorithm as an extension of pattern recognition application accepts the fabric surface image as input. Subsequently runs the algorithm which is trained with the samples of defect-less surface image. Since most of the fabric defect detection classifiers are trained with texture based samples, they tries to detect defects
and returns a binary (black & white) image. Where white denote the texture defects. The following set of images shows the input images and its corresponding output below it.

Figure 3.4 Input surface images with defect in 1st row and its output in 2nd row

This defect detection application however is capacitated with certain user friendly characteristics. They are as follows,

3.3.1 Shift Variation Immunity

Any texture defect detection application is expected to be invariant to horizontal or vertical shift. This is to ensure the user, even if the image which is to be fed horizontally is fed vertically or vice versa the detection algorithm still can manage to detect the defects correctly.
3.3.2 Rotation Variation Operability

By default most of the classifiers are often capacitated to operate correctly even if the input image is rotated approximately ±5 degrees. However if the images is shifted further the texture defect detection algorithm requires precursory training to cope up with the change. In case of industry grade voluminous data processing environments to improve the detection range even under the operational mistakes, higher rotation variation operability is expected to be fine tuned before putting the mechanism at work Karolina et al (2013).

3.3.3 Scale Variation Improvisation

The automatic adaptation feature of various defect detection classifiers makes them naturally capable to adjust to scale variation of approximately ±10 degrees. However if the defect inspection is expected to scale for
further variations then it must be improvised with the samples for each and every scale variation Karolina et al (2013). The following figures illustrate a difference in scale that requires trained samples for each variation.

Figure 3.6 Depicts the categories of scale variations

3.4 SEQUENCE OF STEPS IN AUTOMATION

3.4.1 Image Acquisition

The CCD (charge-coupled device) camera or a CMOS (complementary metal - oxide semiconductor) camera and a frame grabber is usually used for image acquisition process Gonzalez & Woods (2008) Kumar et al (2001). Moreover the resolution is a crucial factor for performing effective defect detection Shweta & Dhirendra et al (2015). Consequently for industry standard applications the high resolution camera is used to detect all the possible defects even though it adversely affects the inspection speed.
3.4.2 Pre-processing

It employs feature extraction techniques to extract essential features from captured fabric surface images. It also deploys any of Median filtering,
histogram equalization, etc to reduce noises and other distortion from images. However Histogram equalization is so effective since it can determine the gray level values and set values essential to achieve uniform gray level distribution in an image Dan et al (2007). This will help for better detection.

3.4.3 Feature Extraction

In this phase the defected and non-defected texture are characterized and analysed. Their relationships or the differentiations help define information that can be used as feature samples Shweta & Dhirendra (2015). The features from textured images are usually represented as feature vectors Ashwani et al (2014). These vectors are then used for discriminating defect from defect-free test cases by measuring values of fabric defects as well as the values for defect-free fabrics Anand et al (2014). There are various methods employable for feature extraction such as threshold base methods, empirical methods, statistical, soft classification techniques etc.
3.4.4 Detection /Classification

This phase will determine and classify the obtained patterns to classes using appropriate detector. The binary classifier will categorize the input Fabric images into normal fabric class or fabric defect class. However to adjust to the varying nature of the feature this requires adapting right technique for better performance Tarek et al 2014.

3.4.5 Post-processing (Making final decision)

Fabric defect identification seems to be complete with detection and classification, however, the residual slipping of some detects termed as false negatives still affect the outcome Shweta & Dhirendra et al (2015). This can impact negatively during sales process and can cause loss to reputation. Therefore a post-processing scheme is applied to improve the detection accuracy to eliminate the false negative possibilities completely or to reduce it to a tolerable rate.
3.5 IMPORTANT SVM KERNEL FUNCTIONS

Kernel methods are often used to detect nonlinear patterns in the data. Supervised learning algorithms (Perceptron, SVM, linear regression, etc) and many unsupervised learning algorithms too can be kernelized (e.g Nonlinear Regression) Robert et al (2001). Even if a linear model such as SVM is used kernel can help it to work in nonlinear data space John (1999). Kernel as its working principle can map data to higher order and higher dimensions until it becomes linear pattern suitable to apply linear model Xu et al (2011). Apart from linear model it is beneficial in nonlinear models as well Alexander et al (2000). For instance a non-linear Classifier can easily and effectively classify the input data into binary Classes with linear boundary Alexandros et al (2017).

3.5.1 Kernel General Definition

Each kernel k has an associated feature mapping φ, Alexandros et al (2017), φ takes input x ∈ X(input space) and maps it to F (feature space)
Kernel $K(x, z)$ takes two inputs and gives their Similarity in F space

$\Phi : X \rightarrow F_k$:

$X \times X \rightarrow \mathbb{R}$,

$k(x, z) = \varphi(x)^{\top} \varphi(z)$ \hfill (1)

F needs to be a vector space with a dot product defined on it also called a Hilbert Space *John et al (1999)*. A Hilbert space is a vector space closed under dot products, such that, the dot product there gives the same value as the function *Robert et al (2001)*. Kernels must also satisfy Mercer’s Condition *Behjat et al (2009)*. If a kernel does not satisfy Mercer's condition then the corresponding problem may not be solved. Mercer's condition is given as for any vector $g(\bar{x})$ such that $\int g(\bar{x})^2 d\bar{x}$ is finite, the following condition should satisfy,

$$\int K(\bar{x}, \bar{z})g(\bar{x})g(\bar{z})d\bar{x}d\bar{z} \geq 0.$$ \hfill (2)

Also a bit work must be constant, symmetric, and can restore the inward item between two focuses in an appropriate element space even if it

Anyway the SVM calculations utilize an arrangement of numerical capacities that are characterized as the bit. The capacity of bit is to take information as info and change it into the required frame. Distinctive SVM calculations utilize diverse kinds of part capacities, for example, straight, nonlinear, polynomial, spiral premise work (RBF), sigmoid and so on John (1999). The accompanying are the most prominent SVM pieces for genuine esteemed vector inputs.

3.5.2 Polynomial kernel

It is a vastly used kernel and it is given as,

\[ k(x_i, x_j) = (x_i \cdot x_j + 1)^d \]

Where d is the degree of the polynomial. If d=1 then it is linear kernel, if d=2 then that gives the significantly applied quadratic kernel John (1999).

3.5.3 Gaussian kernel

It is constructed to be a readily applicable kernel, when there is no prior knowledge available about the data Behjat et al (2009). The equation for
$k(x, y) = \exp \left(-\frac{||x - y||^2}{2\sigma^2}\right)$ \hspace{1cm} (4) Gaussian kernel is;

3.5.4 Gaussian radial basis function (RBF)

RBF can also be applicable when no prior knowledge is available, as well as, it can map data to infinite higher dimensions Robert et al (2001) Cawley & Talbot et al (2010). It is as follows

$$k(x_i, x_j) = \exp(-\gamma||x_i - x_j||^2), \text{ for: } \gamma > 0$$ \hspace{1cm} (5)

Sometimes parameterized using: $\gamma = 1/2\sigma^2$

3.5.5 Laplace RBF kernel

It is a broadly useful bit utilized when there is no earlier learning about the information.

$$k(x, y) = \exp \left(-\frac{||x - y||}{\sigma}\right)$$ \hspace{1cm} (6)

3.5.6 Hyperbolic tangent kernel

It sees widespread usage in neural network due to its capability to provide optimal generalization Cawley & Talbot et al (2010).
\[ k(x_i, x_j) = \tanh(\kappa x_i \cdot x_j + c) \]  
\[ (7) \]

Where \( k > 0 \) and \( c < 0 \)

### 3.5.7 Sigmoid kernel

It is also called as Hyperbolic Tangent Kernel. It can be used as proxy for neural networks and it supports SVM \( John et al (1999) \), it is given as

\[ k(x, y) = \tanh(\alpha x^T y + c) \]

### 3.5.8 Bessel function of the first kind Kernel

It can be used to remove the cross term in mathematical functions.

\[ k'(x, y) = \frac{J_{\nu+1}(\sigma \|x - y\|)}{\|x - y\|^{-\nu(n+1)}} \]  
\[ (8) \]

where \( j \) is the Bessel function of first kind \( Gonzalez & Woods et al (2008) \).

### 3.5.9 ANOVA radial basis kernel

ANOVA can be extremely useful in solving regression problems \( Gonzalez & Woods et al (2008) \). It is presented as follows
The list of kernels that can be used with SVM is quite extensive. However the presented kernels are more stable and are applied for various image processing applications *Cawley & Talbot et al (2010)*. In the following sections after testing varieties of kernels few of the presented kernels are adapted for the proposed work to come-out with effective defect detection algorithms.

\[
k(x, y) = \sum_{k=1}^{n} \exp(-\sigma(x^k - y^k)^2)^d
\]  

(9)