Chapter 3

Application of Clustering Techniques to Textile Data
3.1 INTRODUCTION

In Southern part of India, there is an old saying in Tamil "Aadai Illaatha Manithan Arai-Manithan", meaning "man without dress is half-man". Dress material is of various types. The base materials are made up of cotton, jute, wool, fur and also synthetic varieties. The quality and type of fabric are determined by the properties of yarns used for producing fabrics.

Textiles are now increasingly used for many purposes, from the traditional uses like garments and furniture to others such as conveyor belts, technical textiles and aerospace applications. Probably there are two reasons for this wide range of utilisation, the first being that textile materials cover a wide range of different physical and mechanical properties, and the second is that textile technology is tending to become a science with well established rules and predictable results, so that fabrics can be designed for specific purposes.

The end-uses of textiles decide the way they should be selected and constructed, suggesting that some properties should act in a certain way, while others remain less active. For example, outerwear fabrics need to satisfy some aesthetic, physical and thermal properties as well as being durable. On the other hand, fabrics used for industrial purposes are made for strength and flexibility, and possibly for certain electrical and thermal properties, and so aesthetics are relatively unimportant.
Generally, for any end-use, the mechanical properties of fabrics are of special interest, and studies of how these properties are related to the fabric and yarn properties could help in deciding how to produce a suitable fabric at a minimum cost when its likely range of use is known.

The textile industry depends on the raw materials such as cotton, jute and silk fibres. The fibres obtained from the natural resources are then sent to spinning mills for processing and yarns are produced. Yarn structure and properties are primarily influenced by fibre properties (for example, length, fineness and cross-sectional shape), spinning method (for example, ring, rotor and airjet) and process variables (for example, twist insertion rate, rotor speed, nozzle pressure). The relationship between yarn structure and tensile properties has been studied extensively and a number of statistical models have been developed. Grading of yarns is another important need in assessing textile quality for commercial purposes, since it provides an useful means of expressing yarn standards in the market. Traditionally, it is done by a comparison of measurements of various quality related parameters with their values as recommended in a standard, which is different for different countries. Recently, Rong, Slater and Fei (1994) have used cluster analysis method for grading of yarns in textile industry.

Yarns are woven to produce different types of fabrics. Fabrics may be of different types such as dress materials, shirting, suiting materials etcetera made up of natural fibres or synthetic fibres such as, polyester/viscose. Each fabric will have some properties which can be measured by specified instruments. In the past the quality of fabrics was determined by experience,
that is, judgement by hand and specification of fibre types (wool, cotton, silk). With the rapidly increasing use of synthetic fibres, characterizing the fabric by experience is becoming more and more difficult. Therefore, development of a scientific and practical method will facilitate fabric selection. The first research on measuring fabric properties can be traced back to the European airship programmes around the turn of the century. Kawabata (1980) established the *Kawabata Evaluation System for Fabrics* (KES-F), which is used to measure the mechanical properties of the fabrics. KES-F is shown to offer advantage over other instruments in the routine measurements of the properties. Fabric is tested for tensile, bending, shearing, compression, surface properties and also for thickness and weight.

A number of publications of research papers show that fabric handle received wide attention from scientists and technologists from very early days. Fabric handle has become one of the most active areas of textile research during the past twenty years. Fabric *hand or handle* is defined as the quality of a fabric or yarn assessed by the reaction obtained from the sense of touch. KES-F system of assessment of hand value has been used by fibre, yarn and fabric producers all over the world. Many research workers have used multivariate statistical methods such as cluster analysis, Principal Component analysis in the study of fabric hand. Pan, Zeronian and Ryu (1993) suggest statistical methods such as PCA, Variable Cluster Analysis, D-optimal method and collinearity tests for identifying the most important mechanical properties. Recently, Stearn, D'arcy, Mahar and Postle (1986) employed factor analysis to classify suiting fabrics based on a KES-F data set. Pan, Yen, Zhao and Yang
have discussed classification of fabrics by hierarchical clustering methods.

Discriminant analysis techniques are more suitable for fabric classification and quality prediction in clothing industry. Discriminant analysis can be used to grade the samples based on their overall performance. Multivariate methods have been used in the comparative studies of fabric characteristics [Bishop and Cox, 1994]. Chen and Collier (1997) have used discriminant analysis to categorize the fabrics used for blouses, shirts and suiting using the KES-F instrument data. In brief, it can be concluded that the main purpose of statistical classification techniques is for grading of yarns or fabrics and categorizing different fabric materials, for example, shirting, suiting etcetera based on their mechanical properties. Recently, ANN techniques have been applied to textile industry [Ramesh, Rajamanickam and Jayaraman (1995) and Sette, Boullart and Keikens (1995)].

In this chapter, classification of fabric samples into various categories using statistical techniques is considered for study. The fabric samples are tested for various properties and they are measured using KES-F instrument. Each type of fabric will have a set of properties which differentiate two types of fabric. The handle of fabric determines the softness and roughness of the fabric. Lower the handle force, softer will be the fabric. Earlier work shows that statistical methods applied to various areas of textile industry gives useful and meaningful information regarding the fabrics and yarns. Statistical classification techniques, such as discriminant and cluster analyses, have the ability to categorize the fabric samples into different meaningful groups based
on the measurements made on the sample. From the literature, it is observed that either cluster or discriminant analysis is effectively carried out for textile data. In this present study, we have tried to obtain various groups (clusters) based on the original known group information as well as the clusters obtained on the assumption that the groups are unknown. The highlight of the technique is that clustering is done first to obtain the groups and then discriminant analysis is carried out repeatedly until 100% classification is achieved, thereby allowing for regrouping of sample units. An interesting result is obtained by carrying out discriminant analysis repeatedly using the clustered data set, that is, it shows that there is a possibility of getting different groups with 100% classification when compared to lesser classification rate, say 95%, in the conventional analysis. Step-wise method highlights the variables which contributes in group formation.

The various parameters or variables used in the data sets are discussed in the next section.

3.2 DATA DESCRIPTION OF VARIABLES

The fabric samples are tested for various mechanical properties. The mechanical properties such as the tensile, shear, bending, compression and surface properties of fabric samples are measured using KES-F instrument. The instruments generate both digital and graphical output. Table 3.1 gives an outline of the key parameters involved in the KES-F tests.
The samples are woven to test them for various properties as described below.

### 3.2.1 MEASUREMENT OF THE LOW STRESS MECHANICAL PROPERTIES BY KES-F

**Tensile Properties**

1. **Linearity of the Stress-Strain Curve (LT):** Linearity of the stress-strain curve is defined by \((WT/WL)\times100\) where WL is the tensile energy when the load extension curve is linear from zero strain to EMT and WT is the curve obtained during recovery.

2. **Tensile Energy (WT):** It will give an indication of tensile energy.

3. **Tensile Resilience (RT):** RT is measured by the load-extension curve.

**Bending Properties**

4. **Bending Rigidity (B):** In the KES-F system, the fabric sample is bent to a maximum curvature of 0.25mm\(^{-1}\), the bending rigidity is taken as the average slope of the part of the bending curve between 0.05mm\(^{-1}\) and 0.15mm\(^{-1}\) curvature.

5. **Hysteresis of Bending (2HB):** This is coercive couple taken as a width of the bending hysteresis curve at curvature of 0.1mm\(^{-1}\).
Shear properties

6. Shear rigidity (G) : This is a measure of shear rigidity of fabric which is directly related to the draping quality of the fabrics; these values show the tailoring and comfort aspect of the fabric in garment manufacture.

7. Hysteresis of shear force (2HG) : This is a measure of the hysteresis of the shear force on the shear hysteresis curve at 0.5 degree shear.

8. Hysteresis of shear force (2HG5) : This is a measure of the hysteresis of the shear force on the shear hysteresis curve at 5 degree shear.

Compressional Properties

9. Linearity of the Compression Curve (LC) : It is linearity of compression curve.

10. Work of Compression Curve (WC) : A circular specimen of 2 cm² area of a circle is compressed by two circular plates of steel with 2 cm² area. The velocity of compression is 6.66 micro/sec and when the pressure attains 10gf/cm², the recovery process is measured by the same velocity.

11. Compressional Resilience (RC) :

\[ RC = \frac{WC'}{WC} \times 100 \]

where,

\[ WC' = \text{Work of decompression (J/m}^2) \]

\[ WC = \text{Work of decompression} \]

\[ RC = (\%) \]
It shows the resilience of the material in compression. It is the ratio of work of decompression to work of compression expressed as percentage.

**Surface Properties**

12. **Coefficient of surface friction (MIU)**: It is a measure of the mean value of coefficient of friction between fabric surface and metallic pianomodel surface detector, whose surface is simulated to the finger surface.

13. **Mean deviation of coefficient of friction (MMD)**: This is a deviation of the coefficient of friction measured and has a significant effect on the handle of the fabric.

14. **Surface Roughness (SMD)**: This is a measure of the mean deviation of the surface roughness (mean deviation of thickness (micron)).

15. **Fabric Thickness (T)**: It is the thickness of the fabric in mm.

16. **Fabric Weight (W)**: It is the weight of the fabric in mg/cm².

### 3.3 DATA SET

The Department of Textile Technology, Anna University, is collaborating with the Statistics Department of Madras Christian College for the past one year. The data set measured using KES-F instrument is obtained from the Department of Textile Technology, Anna University, Chennai, India. The KES-F instrument is very costly and for testing one fabric sample it costs over
thousand rupees, thereby costing over a lakh of rupees for the whole data set. The following three data sets are considered for the statistical analysis.

3.3.1 DATA SET 1

Data Set 1 comprises different types of Polyester Fabrics (Regular / Micro fibres). It includes 27 fabric samples with 16 parameters. The Data Set 1 is shown in Table 3.2. Fabric samples A1, A2, A3 belong to polyester cotton (regular filament yarn), A4, A5 depict cotton (regular yarn) while A6, A7, A8 are carbonised polyester cotton (regular yarn). A9, A10, A11, A12, A13 are polyester fabric (roto yarn : regular) and A14, A15 belong to polyester (regular yarn). A16, A17, A18 indicate polyester cotton (micro filament) while A19, A20 depict cotton (micro filament). A21 is carbonised polyester cotton (micro filament). A22, A23, A24 belong to polyester (roto : micro) and A25, A26, A27 are polyester (regular). The data set can be grouped as polyester cotton (regular), cotton (regular), carbonised polyester cotton (regular), polyester (roto yarn : regular), polyester (roto yarn : micro) and polyester cotton (micro). Fabrics woven from these yarns are tested for various mechanical properties. The fabric samples include shirting, suiting and dress materials.

3.3.2 DATA SET 2

Data Set 2 consists of 40 Lyocell/Viscose fabric samples with 16 KES-F parameters. It is shown in Table 3.3. Fabric samples B1 to B10 are woven lyocell fabrics, while knitted lyocell fabrics are represented by samples B11 to B18. B19 to B29 depict fabrics with different weave structures. The
remaining 11 samples, B30 to B40 consist of miscellaneous fabrics, namely, laundered and peach finished samples of jute/silk, cotton long cloth and suiting fabrics.

3.3.3 DATA SET 3

Chemically Treated Polyester fabric samples constitute Data set 3. Sixteen KES-F properties are measured for the 38 fabric samples. Data set 3 is given in Table 3.4. The polyester fabrics are subjected to alkaline hydrolysis treatment. The different treatments applied to polyester fabrics are heat setting, ethylene diamine and boiling water shrinkage. Also jute polyester fabrics are subjected to alkaline hydrolysis. Samples C1 to C12 are 100% polyester sarees (400 tpm). Micro-chiffon (100% polyester) sarees (2000 tpm) are represented by the fabric samples C13 to C25. C26, C27 are micro chiffon 100% polyester (2000 tpm) material treated by boiling water shrinkage. C28, C29, C30 are 100% polyester sarees (400 tpm) with repeated hydrolysis treatment. C31, C32, C33 are polyester cotton sarees with alkaline oxidation treatment. C35, C36 are polyester sarees (400 tpm) treated with caustic soda and ethylene diamine (NaOH+EDA) while C37, C38 form micro-chiffon sarees (2000 tpm).

The three data sets are combined together, which consists of 105 fabric samples with 16 KES-F parameters. In the present study, the combined data set as well as individual data sets are analysed. All the data set were subjected to normality test and equality of variance test and the same ascertained. A detailed discussion is presented in next section.
3.4 DISCRIMINANT ANALYSIS

The discriminant analysis (DA) for fabric samples is carried out with the known groups, namely Data set 1, Data set 2 and Data set 3. The 105 data set consisting of three groups is considered for the analysis. Direct method as well as step-wise method are applied and the results are obtained. In order to discuss the characteristic features of each of the group, a concept, similar to fuzzification of values of the 16 parameters, is introduced. The minimum, maximum and range of each of the parameter are obtained. Then the range of values of each parameter is split into three intervals, namely, low, medium and high. The value of a parameter is coded as high (H) if the value is greater than or equal to minimum + (2.0)*(range)/3.0 and low (L) if the value is less than or equal to minimum + range/3.0. Otherwise, the value is taken to be medium (M). When a cluster or group is dominated mostly by low and medium category of a particular parameter, it is assumed to possess low-medium characteristic of that parameter. Similarly for medium-high category. This is a kind of fuzzification of fabric parameter values. These fuzzy codes, namely, L, M and H are used in the tables that are referred to in the following discussion. One can also use other methods of fuzzification. In the discussion that follows, low (list) refers to the low value of the parameters in the list. Similarly, for low-medium, medium, medium-high and high categories.

3.4.1 DIRECT METHOD

The direct method uses all the 16 fabric parameter values. Discriminant analysis yields 100% correct classification, that is, fabric samples A1 to A27
fall into Group 1. Similarly samples B1 to B40 and C1 to C38 are also classified into two different groups, namely, Group 2 and Group 3 respectively. The mean vectors of known groups is given in Table 3.5. Fishers linear discriminant functions are also obtained and they are shown in Table 3.6. Table 3.7 gives fuzzy code of KES-F parameters for known groups.

The Group 1 consists of Polyester Fabrics (regular/micro). This group is characterized by high (LT, RT), medium (LC, RC, MIU) and low (SMD, T,W) (Table 3.7). Lyocell/viscose Fabrics constitute Group 2, with medium-high (W, MIU), medium (SMD, T) and low-medium (LT, RT, LC, RC) properties. The high (LC), medium-high (RT, RC), medium (LT, MIU) and low-medium (SMD, T, W) properties dominate Group 3 that consists of chemically treated polyester fabrics. The group formation is shown graphically in Figure 3.1.

3.4.2 STEP-WISE METHOD

In the step-wise method, the parameters are chosen or removed in a step-wise process. At the first step LC is selected and then RT, LT, 2HG, T, WC, RC, B, G, 2HB, 2HG5 and W are selected in successive steps. Step-wise process also yields 100% classification. This method also classifies 27 polyester (regular/micro), 40 lyocell/viscose and 38 chemically treated polyester fabrics into three different groups. Since the original groups are the same as the groups obtained by step-wise method, the selected parameters are explained with respect to the original groups. LT is high, low-medium and medium for Groups 1, 2 and 3 respectively (Table 3.7). RT is high for Group 1 while it is low-medium for Group 2. Group 3 possesses medium-high (RT). The Group
Figure 3.1 Known Groups of Textile Data

- 105 Sample Units

GROUP
- Group Means
- Data Set 3
- Data Set 2
- Data Set 1
1 has medium (LC, RC) while the Groups 2 and 3 possess low (LC, RC) and high (LC, RC) respectively. Groups 1, 2 and 3 are characterized by low, medium-high and low-medium categories of fabric thickness and fabric weight respectively.

3.5 CLUSTER AND DISCRIMINANT ANALYSES

Assuming that the 105 sample units constitute different unknown groups, the fabric samples are subjected to the cluster analysis followed by repeated discriminant analysis described below.

Generally, K-means algorithm uses the euclidean distance as the distance measure. The technique applied here makes use of the centers obtained from the K-means algorithm, without iteration, as the initial weights. This will facilitate the network to converge fast. These weights connect the input nodes to the nodes in the output layer. The clustering technique updates the weights of the winning nodes and neighborhood nodes as explained in Chapter 2. The final clusters are obtained using the proposed clustering method that makes use of Mahalanobis distance measure.

The clustered data set is then subjected to discriminant analysis repeatedly by considering the classification of groups obtained in iteration t as the input into the next iteration (t+1), until a cent percent classification is achieved. This procedure would work satisfactorily for well separated groups. If the convergence is not met beyond a specified number of cycles, the procedure should be terminated and the groups with minimum
misclassification rate will have to be taken as final groups. It is to be noted that the concept of performing repetitive discriminant analysis is new in forming clusters.

The step-wise discriminant analysis may be used to determine the characterizing parameters. We attempted to classify the fabric samples into two clusters, three clusters and so on, up to ten clusters. It is observed that 3 clusters alone differentiated the given fabric samples into meaningful groups. Higher number of clusters yield only a few samples in each group (one or two members only) which does not provide useful information. The final results obtained after discriminant analysis are discussed in the following section.

3.6 RESULTS AND DISCUSSION
3.6.1 CLUSTER ANALYSIS OF 105 SAMPLE FABRICS

The cluster analysis of given data set of 105 samples yielded three clusters with 28, 36 and 41 fabric sample units in three cycle (Table 3.8). Cluster 1 consists of polyester cotton (regular/micro), carbonised polyester, dyed long cloth, 100% polyester sarees (400 tpm) and alkaline treated polyester cotton sarees. The second cluster includes polyester (roto: regular), 100% polyester sarees (400 tpm, 2000 tpm) and repeated hydrolysis treated polyester fabrics. Woven and knitted lyocell, different weave structure fabrics and micro chiffon sarees form the third cluster. It is seen that, in this case polyester cotton, polyester and lyocell/viscose fabrics are grouped together. This shows that the fabric samples are grouped naturally. Discriminant analysis of the clustered samples yielded 100% classification in 3 cycles. The different
groupings of fabric are due to the reason that opportunities are given to all those nodes which are close to an input sample unit X, to get updated in the proposed technique. Normally the process of updating is restricted to only one node in traditional clustering techniques. There may be some hidden properties of the samples which may make them to associate with other groups. Here we observe that 20% of original samples are reallocated to different groups and still 100% classification is obtained with the new groups formed. The number of sample units in three clusters for 105 fabric samples. cluster centers, Fishers linear discriminant function (LDF) and the rearrangement of the sample units of the three original data sets into three clusters are given in Table 3.8, Table 3.9, Table 3.10 and Table 3.11 respectively. Fuzzy codes of the values of parameters in 3 clusters are given in Table 3.12. Pictorial representation of the three clustered groups as obtained by discriminant functions is shown in Figure 3.2.

It is found that the Cluster 1 is characterized by low-medium (T, W, B, 2HB, G, 2HG, 2HG5), medium (LC, RC), medium-high (LT) high (RT) properties (Table 3.12). Cluster 2 has fabric thickness, weight, bending and shear properties in the low category. It also possesses medium (LT) and medium-high (RT, LC, RC) properties. Low (LC, RC), low-medium (LT, RT), medium (bending and shear) properties and medium-high (T, W) characterize Cluster 3.

Next we proceed with the grouping of individual data sets, namely, Data set 1, Data set 2 and Data set 3. First we discuss the grouping of sample units belonging to Data set 1 consisting of 27 sample fabrics.
Figure 3.2  Clustered Groups of Textile Data

- 105 Sample Units
3.6.2 CLUSTER ANALYSIS OF DATA SET 1

3.6.2.1 CLUSTER ANALYSIS OF DATA SET 1 - 2 CLUSTERS

Data set 1 consisting of 27 fabric samples are classified into two, three and four clusters using the clustering technique. The clustering procedure converged in one cycle.

In the case of two clusters, the first cluster consists of 18 fabric samples belonging to regular and micro types of polyester cotton, cotton, carbonised polyester cotton and polyester (Table 3.13). It is seen that the first cluster is characterized by the low-medium (LC), medium (B, T) and medium-high (2HG, 2HG5, WC) (Table 3.16). Nine fabric samples belonging to polyester (roto : regular), polyester (roto : micro) and carbonised polyester cotton (regular) constitute second cluster. The second cluster possesses the properties of low (B, 2HB, 2HG5, WC, T), medium (LT), medium-high (LC) and high (RC). The number of sample units and the mean vectors of the two clusters of Data set 1 are given in Table 3.13 and Table 3.14 respectively. Table 3.15 and Table 3.16 show Fisher's LDF and fuzzy codes respectively. Repetitive discriminant analysis procedure converged in just one cycle to form the two clusters. Next we attempt to group Data set 1 into three clusters.

3.6.2.2 CLUSTER ANALYSIS OF DATA SET 1 - 3 CLUSTERS

The 27 fabric samples are split into three clusters of sizes 8, 10 and 9 by the proposed procedure in just one cycle (Table 3.17). The first cluster consists of polyester fabrics (roto : regular and micro) possessing low (T, WC,
B, 2HB), low-medium (G, 2HG, 2HG5, LT, WT), medium-high (LC) and high (RC) (Table 3.20). The second cluster is characterized by medium-high (B, 2HB, SMD), medium (WC, RC), low-medium (T) and low (LC, W) properties. It consists of polyester cotton (regular and micro) and carbonised polyester cotton (regular and micro) fabrics. Cotton (regular and micro) and polyester (regular) form the third cluster. It is observed that Cluster 3 possesses low (RT, RC), low-medium (bending property), medium (LC) and medium-high (2HG, WC). The number of sample units and the mean vectors of Data set 1 for 3 clusters are given in Table 3.17 and Table 3.18 respectively. Table 3.19 and Table 3.20 show Fisher's LDF and fuzzy codes respectively. Figure 3.3 gives the graphical representation of the 3 clusters of Data set 1 at the conclusion of discriminant analysis. The number of cycles required for the repetitive discriminant analysis to converge to 3 clusters is 1. Cluster analysis for obtaining four groups is described in the next section.

3.6.2.3 CLUSTER ANALYSIS OF DATA SET 1 - 4 CLUSTERS

Four clusters are formed for Data set 1 using the proposed algorithm (Table 3.21). The algorithm converged in one cycle. The first cluster of the four clusters possesses polyester cotton (regular and micro) and carbonised polyester cotton (regular and micro) samples with low (LT, WT, LC), low-medium (2HG, 2HG5, W), medium (WC, RC, T) and medium-high (SMD, MMD) properties (Table 3.24). Three samples of carbonised polyester cotton (regular) and polyester (roto: regular) form the second cluster. This cluster is characterized by low (T, W, bending and shearing) properties. The third cluster consisting of 9 samples is highlighted by low (RC, RT), medium (LC),
Figure 3.3 Clustered Group of Textile Data Set 1 - Polyester Fabrics - 3 Clusters

Function 1

Function 2

Cluster 1
Cluster 2
Cluster 3
Cluster Centers
medium-high (shearing) and high (WC) properties. This cluster includes cotton (regular and micro) and polyester (regular) samples. Six sample units of polyester (roto: regular and micro) form the last group. Cluster 4 also has low (T, W, bending and shearing), medium-high (LC) and high (RC) characteristics.

The number of sample units and the cluster centers for Data set 1 for 4 clusters are given in Table 3.21 and Table 3.22 respectively. Table 3.23 and Table 3.24 give Fisher's LDF and fuzzy codes of parameters in four clusters of Data set 1. The four clusters of Data set 1 are shown in Figure 3.4. In the next section, we proceed with the analysis of Data set 2.

3.6.3 CLUSTER ANALYSIS OF DATA SET 2

3.6.3.1 CLUSTER ANALYSIS OF DATA SET 2 - 2 CLUSTERS

Data set 2 is subjected to the clustering and discriminant analysis procedures for obtaining different clusters. Firstly, the data set is allowed to divide into 2 groups and subsequently, clusters of sizes 9 and 31 are obtained (Table 3.25). The first cluster consists of knitted lyocell and pin head crepe samples. The second cluster includes woven lyocell, fabrics with different weave structure and miscellaneous samples. Low (bending, shearing, RC), medium (MIU, MMD) and high (WT) characterizes Cluster 1 while Cluster 2 possesses medium (LT, WT, RT) and medium-high (RC, W) (Table 3.28). The number of sample units and the mean vectors of Data set 2 for 2 clusters are given in Table 3.25 and Table 3.26 respectively. Table 3.27 and Table 3.28 show Fisher's LDF and fuzzified code respectively. Grouping Data set 2 into three clusters is described in next section.
Figure 3.4 Clusters of Textile Data Set 1

- Polyester Fabrics - 4 Clusters

Cluster Centers
Cluster 4
Cluster 3
Cluster 2
Cluster 1
3.6.3.2 CLUSTER ANALYSIS OF DATA SET 2 - 3 CLUSTERS

Three clusters of sizes 8, 9 and 23, having knitted lyocell in the first, miscellaneous (control long cloth (washed), control dyed long cloth and peach finished) in the second, and woven lyocell and different weave structure fabrics in the third, are formed out of the Data set 2 (Table 3.29). The first cluster has high (LT, LC), medium-high (RT) and low (WT) properties whereas Cluster 2 is characterized by high (fabric weight, WT), medium (SMD, MIU) and low (LT, RT) (Table 3.32). The third cluster possesses medium (tensile property) and low (LC). The number of sample units and the cluster centers for Data set 2 for 3 clusters are given in Table 3.29 and Table 3.30 respectively. Table 3.31 and Table 3.32 show Fisher’s LDF and fuzzified code respectively. Figure 3.5 shows the three groups of Data set 2.

It is seen that the formation of four clusters is the same as three clusters with the exception that one sample unit is moved to the fourth cluster. So we are not discussing about the 4 clusters for Data set 2. Having discussed about the formation of groups with respect to Data set 1 and Data set 2, we next proceed with the cluster analysis of Data set 3.

3.6.4 CLUSTER ANALYSIS OF DATA SET 3

3.6.4.1 CLUSTER ANALYSIS OF DATA SET 3 - 2 CLUSTERS

The two clusters of Data set 3 have 23 samples in Cluster 1 and 15 samples in Cluster 2 (Table 3.33). The procedure converged in one cycle. Cluster 1 consists of chemically treated 100% polyester sarees (400 tpm, 2000
Figure 3.5 Clustered Groups of Textile Data Set 2

- Lyocell/Viscose Fabrics - 3 Clusters
tpm) while alkaline treated polyester micro chiffon sarees (2000 tpm) form Cluster 2. Low (bending, shearing, fabric thickness, weight), medium (LC, MIU, SMD) and medium-high (RC) contribute to the formation of the first cluster while second cluster is characterized by medium-high (MIU), low-medium (compressional properties) and low (MMD) (Table 3.36). The number of sample units and the cluster centers for Data set 3 for 2 clusters are given in Table 3.33 and Table 3.34 respectively. Table 3.35 and Table 3.36 represent Fisher's LDF and fuzzified code respectively. Formation of three clusters relating to Data set 3 is described below.

3.6.4.2 CLUSTER ANALYSIS OF DATA SET 3 - 3 CLUSTERS

When Data set 3 is subjected to cluster analysis for forming 3 clusters, it converged in one cycle. The cluster sizes are shown in Table 3.37. In the case of three clusters, Clusters 1 and 3 are characterized by low (bending, shearing) properties (Table 3.40). The 13 samples correspond to 100% polyester sarees (400 tpm, 2000 tpm). Cluster 1 possesses medium-high (LC, RC), medium (MIU) and low (T, W) properties. The second cluster consisting of 20 samples shows that RC, LC are at low-medium. These samples are 100% polyester sarees (400 tpm, 2000 tpm) with different treatments. The third cluster is formed with the 100% polyester (2000 tpm) micro chiffon sarees (boiling water shrinkage) with 5 samples. It is dominated by high (MIU) and low (RC, LC). The number of sample units and the mean vectors of Data set 3 for 3 clusters are given in Table 3.37 and Table 3.38 respectively. Table 3.39 and Table 3.40 present Fisher's linear discriminant functions and fuzzy codes.
respectively. Figure 3.6 gives the graphical representation of the three groups. Next we proceed with the discussion on four clusters of Data set 3.

3.6.4.3 CLUSTER ANALYSIS OF DATA SET 3 - 4 CLUSTERS

The Data set 3 is split into four clusters with 4, 8, 20 and 6 sample units (Table 3.41). The clustering procedure converged in one cycle. Cluster 1 consisting of 2000 tpm micro chiffon sarees (boiling water shrinkage) is characterized by high (MIU), medium (weight, SMD) and low (RC, LC) (Table 3.44). Cluster 2 is characterized by medium-high (MIU, LC) and medium (RC). The samples in Cluster 2 are treated 100% polyester sarees (2000 tpm). Cluster 3 consists of polyester sarees (400 tpm). It possesses medium (MIU), low-medium (RC, LC) and medium-high (RT) properties. Cluster 4 has medium (MIU) and high (RC) properties, which consists of polyester sarees (400 and 2000 tpm). The number of sample units and the cluster centers for Data set 3 for 4 clusters are given in Table 3.41 and Table 3.42 respectively. Table 3.43 and Table 3.44 show Fisher's LDF and fuzzified code respectively. The four groups as differentiated by discriminant analysis are shown in Figure 3.7.

3.7 SUMMARY

A textile industry uses fibres, yarns and fabrics for testing their properties. At the initial stage yarns are tested for their quality and graded. Yarns are used for producing fabrics. These fabrics can be classified according to weave structure, knitting method, base material used such as cotton, jute,
Figure 3.6 Clustered Groups of Textile Data Set 3

- Chemically Treated Fabrics - 3 Clusters
Figure 3.7 Clustered Groups of Textile Data Set 3

- Chemically Treated Fabrics - 4 Clusters

Cluster Centers

Cluster 4  Cluster 3  Cluster 2  Cluster 1

Function 1

Function 2
silk or synthetic material such as polyester etcetera, softness or roughness of the material, usage of the fabrics such as the dress material. The categorization is very essential for the textile industry. Textile technologists have introduced various methods for solving the above mentioned problems. Measurements of various properties are obtained using the Kawabata instrument. To classify a fabric based on measurements, some scientific methodology is to be adopted. Statistical classification techniques are very useful in such situations. In case of known groupings, it is easier to use discriminant analysis.

Fisher's linear discriminant functions are constructed for the three known groups of textile data. A cent percent classification is achieved for known groups, indicating that the three groups are well separated. Suppose, there arises a situation where the groupings are unknown then cluster analysis is carried out. But it is difficult to say whether the clusters obtained are correct or not. In such a case the techniques suggested in this Chapter are very useful. It is proposed to apply ANN based cluster analysis first and then the discriminant analysis is used repeatedly to get the clusters refined. A cent percent classification is achieved for the clusters derived using our proposed technique. Cluster analysis is applied to the textile data and the properties of clusters with respect to 2-clusters, 3-clusters and 4-clusters are discussed separately. Discriminant functions are provided for classification purposes in each case. The formation of the clusters are presented in the form of charts.