ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

A SURVEY ON WOVEN FABRIC DEFECTS

YAŞAR ÇIKLAÇANDIR Fatma Günseli[1], UTKU Semih[2], ÖZDEMİR Hakan[3]

[1,2] Dokuz Eylul University, Faculty of Engineering, Department of Computer Engineering, Tinaztepe Campus Buca, 35397, Izmir, Turkey, E-Mail: fatmagunseli.yasar@ogr.deu.edu.tr, semih@cs.deu.edu.tr

[3] Dokuz Eylul University, Faculty of Engineering, Department of Textile Engineering, Tinaztepe Campus Buca, 35397, Izmir, Turkey, E-Mail:h.ozdemir@deu.edu.tr

Corresponding author: ÖZDEMİR, Hakan, E-mail: h.ozdemir@deu.edu.tr

Abstract: *There are many studies in the literature to find and identify woven fabric defects. However, the systems developed have been designed to identify only certain defects due to the large number of defect types. Moreover, a method that works well for identifying a defect type may not work for another defect type. In addition, some mistakes are easy to recognize, while others are difficult to recognize. In this study, different clustering and classification techniques have been investigated and studies detecting and recognizing fabric defects using these techniques have been investigated. Clustering algorithms are often used to detect defects while classification methods are used to recognize the defect types. When we look at the literature, the most common clustering algorithm for fabric defect recognition is K-means algorithm, while the most common classification technique is neural networks. In general, neural networks have been used in the vast majority of studies. The automatic recognition of fabric defects has not yet achieved the desired level of success. Approximately 80 percent of studies conducted on this field have only developed a model, but have not compared the method they used with other methods. So, very little work has been tested in more than one method.*

Key words: *Image processing, textile, woven fabric, clustering, classification, fabric defects.*

1. INTRODUCTION

Defect detection systems have been developed to automate systems controlled by human power. There are many advantages of automatic detection; reducing the loss of human power, decreasing the time and cost required for the control, giving more accurate results, being recorded during the detection to prevent next defects [1]. Textile is one of the areas which automatic defect detection systems are used. There are more than 70 different kinds of defects that originate from the machine during fabric production and these defects reduce the quality of the fabric. Fabric defects that occur during fabric production originate from machine or yarn. They can be divided into defects in the warp direction and defects in the weft direction. Ala and İkiz [2] have encountered 3211 defects in 140062 meters of fabric in their study.

Detection of defects based on human power brings problems. According to Dorrity et al.'s study, even a highly trained staff in the field of quality control can detect about 70% of defects in fabrics [3]. In addition, the control is limited to the working time of staff. Some of the automated systems in this area are intended to detect the defects only, and some of them classify them after detecting the defects. Due to the large number of defect types that can occur in fabrics, studies to classify defects are only making this classification for certain defect types.

In this study, the systems that detect and recognize the fabric defects are examined in two groups, one based on clustering and the other based on classification. In Section 2, we refer to clustering algorithms and examine some studies that use these algorithms to perform defect detection in the fabric. In addition to that, K-Means algorithm is examined in detail. Classification algorithms, related some studies and neural networks (the most used classification technique in fabric defect identification) are mentioned in Section 3. Besides, Section 4 mentions general conclusions.

2. CLUSTERING ALGORITHMS

Clustering is an unsupervised learning technique that groups data according to their similarities [4]. So, each cluster is a collection of similar objects. There are many clustering algorithms and they are divided into five main groups according to the methods they use. The first method is the partitioning based clustering algorithms. Clustering operation is started from one cluster that covers all objects. Then, partitioning is performed iteratively. K-Means [5], K-Medoids [6] and K-Modes [7] are the most known clustering algorithms based on partitioning. Second is the hierarchical clustering. It can performed using two types: Agglomerative and Divisive. Tree structure is used in both types. Divisive method is a top-down method while agglomerative method is bottom-up. There is one cluster in divisive method. Besides, the number of elements determines the number of clusters in agglomerative method. BIRCH (Balanced Iterative Reducing and Clustering using Hierarchies) [8], CURE (Clustering Using REpresentatives) [9], ROCK (RObust Clustering using linKs) [10] and Chamelon [11] are some of the most known hierarchical based clustering algorithms. Third is the density based clustering. Objects are divided into three groups; core, border and noise in this clustering type. Neighbourhoods are taken into account for each object. Clusters with different shapes can be discovered in density based algorithms. DBSCAN [12] and OPTICS (Ordering Points to Identify the Clustering Structure) [13] are the most known clustering algorithms based on densities. The fourth method is grid based clustering. Clusters are formed based on the grid structure [14]. Data is partitioned into cells. Clustering is done by measuring the cell densities. CLIQUE (CLustering In QUEst) [15], STING (STatistical INformation Grid) [16] and WaveCluster (WAVElet based CLUSTER) [17] are the most known grid based clustering algorithms. The fifth and the last one is model based clustering. It is assumed that data objects are created by a model. Then, they are associated with each other based on some strategies. EM (Expectation-Maximization) is the most known model based clustering algorithm [18].

According to the research done, partitioning based clustering algorithms [19], [20], [21] and model based clustering algorithms [22] are used in fabric defect detection. Bu using 45 samples, missing warp, missing weft, oil stains and holes were detected. The clusters are correctly determined when the membership degrees of the clusters are examined [19]. By using two dataset; 1st dataset: box, star and dot patterned fabrics (85 fabrics with defect, 81 fabrics without defect), 2nd dataset: three different fabric types (plain and twill jeans fabric, viscous patterned fabric and plain linen fabric) 28 fabrics with defect, 12 fabrics without defect, hole, broken end, thick bar, thin bar, multiple netting, and knot were detected with a success rate of 95% [20]. In another study [21] defects were detected with a success rate of 96% in low computation time. Eeight different defect types were detected with model based clustering giving the best and effective result [22].

2.1 K-Means Algorithm

One of the most known algorithms is K-Means algorithm. k is the number of clusters and the algorithm divides the data to k groups. At the beginning, k cluster centers are determined. Each object is assigned to the cluster, which has nearest cluster center to this object. The distance between objects and cluster centers is generally calculated using Euclidean distance formula. m is a cluster center and p is a point in a dataset. Euclidean distance between m and p is calculated. n denotes the size of the data in the equation. After all points have been assigned to the closest cluster, the new cluster centers are calculated. This process continues until the cluster centers are stable.

Although K-Means algorithm is widely used, it has some disadvantages: 1) The result depends on the k parameter input, and determining the best parameter for large and multidimensional data becomes a problem. 2) Identification of the initial cluster centers can be in various ways. Determination of the cluster center in different ways can change the result. 3) In addition to these, this algorithm does not give good results for overlapping data sets.

3. CLASSIFICATION ALGORITHMS

Classification algorithms, unlike clustering algorithms, are a supervised learning technique. The number of classes and the characteristic features of the classes are known in advance. Objects are grouped into classes whose properties are known. Some classification techniques are Decision Trees, Bayesian Classifier, Support Vector Machine (SVM), K Nearest Neighbour (KNN), and Neural Networks (NN). The most common technique used to detect fabric defects is neural network and the support vector machine is second. Decision trees are structures that divide the data into groups by applying decision rules. Each class has a label. Decision rules are applied until the elements in each class have the same label (until homogeneity in classes is achieved). In the study of Hanmandlu and his colleagues to find defects in fabrics, the features introduced by the approaches of Local Directional Patterns (LDP), Local Binary Patterns (LBP), Speeded up Robust Features (SURF) and Scale Invariant Feature Transform (SIFT) are used in the fuzzy decision tree [23]. Experimental results show that the properties obtained by the LDP approach are more successful than the properties obtained from other approaches in determining the fabric defect. Bayesian classifier performs a statistical calculation, using a quantity of training data inserted into the system before, to estimate which class the test data belongs to. The more elements the training data has, the more certain it is to find out which class the test data belongs to. The algorithm runs according to a k value entered in the K-nearest neighbour technique. For each element, the nearest k elements of this element are looked at. To find out which class an element belongs to, the k elements around it are looked up. The assignment system of this element depends on the surrounding elements, which are in majority. Distance calculations are made to find the nearest elements and the Euclidean distance measure is usually used when making this calculation. The most common classification method for detecting fabric defects is artificial neural network. Artificial neural networks are mentioned in Section 3.1. Support vector machine is divided into linear and non-linear support vector machines. In Linear SVM, the optimal decision line that divides the data into two is determined and the element to be classed is assigned to a class according to this decision line. In non-linear SVM, data is moved to a space, which has dimension larger than the size of the input space, and the multiple planes, which the data can be best separated, are searched in this space.

There are studies using classification algorithms to find the fabric defects and the type of defects: By using 128 images (70 images for training, 58 images for testing) colour yarn, spot, missing yarn and hole were detected with Bayes technique [24]. Fabrics without defects were determined with a 100% success rate. Total success rate is 99.19%. A light-weighted 100% cotton plain-woven raw fabric was used for experiments of KNN [25]. Hole, tear, nep and foreign yarn were detected. Defects were recognized with a 96% success rate. Types of the defects and locations of them were recorded in the developed interface. By using a camera with 512 × 512 pixel resolution, weft lacking, warp lacking, hole and oil stain were detected with NN [26]. The defects of warp lacking and weft lacking were recognized with a success rate of up to 95%, while the defects of hole and oil stain were recognized with a 100% success rate. By using 144 gray level images (Eight different fabric defects, 16 samples for each defect type) for network training and test steps, double ends, double picks, missing end, missing pick, hole, light filling bar, cobweb and oil stain were detected with NN [27]. Fuzzy neural network has superior classification ability than neural network according to the experiments. By using 45 samples, warp threads, weft threads, oil stains and hole were detected with NN [28]. It is seen that high performance is obtained when the system is tested using the regression curve. By mading tests on the images of fabrics, 256 × 256 pixels and 8 bit resolution, in NN, while mispick, netting multiplies and thin bar were detected for twill woven fabrics, double-weft, thin bar, broken ends and slack pick were detected for plain woven fabrics [29]. The system developed is quite successful and it has low cost. By using images taken by a camera with a 512 × 512 pixel sensor in SVM, missing yarn, spot, hole and oil stains were recognized with a 94.84% success rate. [30]. Oil patch, oil warp, broken warp, oil weft, hair and sundries were detected with SVM on 500 real fabrics [31]. The developed system is successful in finding and classifying common monochrome cloth defects. Defects were recognized with a success rate of up to 94%. By using databases of Parvis (1117 elements) and Tilda (1333 elements) in SVM, thin bar, broken end, thick bar, double weft, slack end, missing draw, wrong draw, bad selvage, oil stain, missing weft, loom fly and without defect were recognized with a success rate of 99.11% for Parvis database, while slack end, broken end, hole, rip, kink, oil stain, missing weft, unrelated corpus and without defect were recognized with a success rate of 92.87% for Tilda database [32]. By using Tilda database in SVM, broken end, hole, kink, oil stain, missing weft, unrelated corpus and without defect were detected [33]. When the LBP was used, 85.2% of the defects were successfully classified, while 79.9% of them were classified when the co-occurrence matrix was used. In addition, LBP is more advantageous in terms of computation time.

3.1 Neural Network

The artificial neural networks used for the first time in the work of McCulloch and Pitts in the 1940s have received considerable attention, especially since the 1980s. It has advantages like high learning ability, low cost, consistency, adaptability to various fields [34]. Artificial neural networks are the systems, which the working structure of the human brain is sampled and developed. The network that neurons connect to each other has the ability to learn. The learning process that the person performs from birth is modelled on artificial neural networks and the system is trained by using examples. In the literature, most of the studies to classify fabric defects use neural networks. The learning phase in the artificial neural network is performed by inputs. Each input is multiplied by its weight indicating the effect on the artificial neural cell. All the products are summed and net input is calculated. Then, the output of this cell is computed using an activation function. The output obtained in one cell can be an input of another cell. In some artificial neural networks, outputs from one layer are fed back to the previous layer. These networks are called feedback neural networks.

4. CONCLUSION

In this study, clustering algorithms, which are unsupervised learning technique, and classification algorithms, which are supervised learning techniques, are mentioned and studies using these algorithms in fabric defect recognition are examined. When we look at the literature, the most common clustering algorithm for fabric defect recognition is K-means algorithm, while the most common classification technique is neural networks. In general, neural networks have been used in the vast majority of studies. Clustering algorithms are used to detect defects [19-22], while classification methods are used to recognize the defect types [24-33]. The defects of missing warp and missing weft are recognized with a success rate of up to 95%, while the defects of hole and oil stain are recognized with a 100% success rate in the study performed by Kuo and Lee [26]. Some defect types are easily classified while recognition of some defects is difficult. It is necessary that both can classify the same defects in order to compare the performance of two studies. The study performed by Mottalib et al. [24] give the highest success rate (99.19%) according to our examinations. They use Bayesian classifier. It may be concluded that studies on fabric defect recognition using the Bayesian classifier should be increased to achieve a good level of success.

The automatic determination of fabric defects has not yet achieved the desired level of success. Approximately 80 percent of studies conducted on this field have only developed a model, but have not compared the method they used with other methods. So, very little work has been tested in more than one method.

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