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Fabric defect detection systems and methods—A systematic literature review

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ABSTRACT

This paper presents a comprehensive literature review of fabric defect detection methods First, it briefly explains basic image acquisition system components such as camera and lens. Defect detection methods are categorized into seven classes as structural, statistical, spectral, model-based, learning, hybrid and comparison studies. These methods are evaluated according to such criteria as the accuracy, the computational cost, reliability, rotating/scaling invariant, online/offline ability to operate and noise sensitivity. Strengths and weaknesses of each approach are comparatively highlighted. In addition, the availability of utilizing methods for weaving and knitting in machines is investigated. The available review studies do not provide sufficient information about fabric defect detection systems for readers engaged in research in the area of textile and computer vision. A set of examination for efficient establishment of image acquisition system are added. In particular, lens and light source selection are mathematically expressed.

1. Introduction

In textile industry, fabric production is usually done on weaving and knitting machines. Fabric is produced from textile fibers. Textile fibers are generally manufactured with natural element such as cotton. A fabric defect corresponds to a flaw on the manufactured fabric surface. In particular, fabric defects result from processes such as machine defects, faulty yarns, machine spoils and extreme stretching. More than 70 kinds of fabric defect are defined by the textile industry [1]. Most of defects occur either in the direction of motion or perpendicular to it. In terms of quality standards, the defects on the fabric surface are categorized into two: surface color change and local texture irregularity [2]. Six common fabric defects are shown in Fig. 1. Float (Fig. 1(a)) is caused by breaking of needles, weft curling (Fig. 1(b)) is caused by inserting a highly twisted weft thread, and a slub (Fig. 1(c)) can be caused by thick places in the yarn or by fly waste being spun in yarn during the spinning process. Hole (Fig. 1(d)) is a mechanical fault caused by a broken machine part. Stitching (Fig. 1(e)) is a common fabric defect. This defect is a result of any undesired motion of the main or auxiliary loom mechanisms. Rust stains (Fig. 1(f)) are caused by lubricants and rust. Not only do such serious defects make the sale of the fabric impossible, they also lead to the loss of revenues [3]. A fabric defect detection system improves the product quality. As a result, automated fabric defect detection systems to manufacture the high quality of textile products are in increasing demand. This automated system is done by identifying the faults in fabric surface using the image and video processing techniques.

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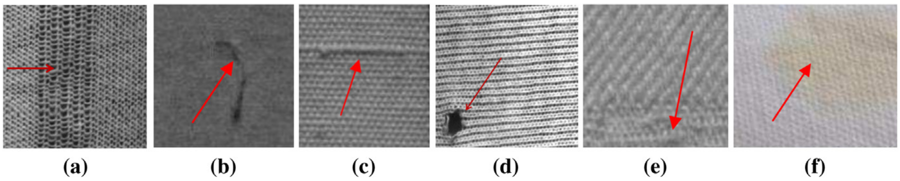

Fig. 1. Example defects namely (a) needle breaking, (b) weft curling, (c) slub, (d) hole, (e) stitching (f) rust stains. (Arrows point to defective regions.).

Fabric defect detection is the determination process of the location, type and size of the defects found on the fabric surface. Generally, human inspection is used for fabric defect detection. It provides instant correction of small defects, but human inspection cannot detect errors due to carelessness, optical illusion and small defects [3–5]. However, human inspection fails on detection defects in terms of accuracy, consistency and efficiency, as workers are subject to boredom and thus inaccurate, uncertain inspection results are often occurred. Thus, automated fabric inspection becomes an efficient method forward to improve fabric quality [6,7].

In automated inspection, defect detection is carried out during the production process. In real-time inspection, these systems detect the defect and are able to stop the production process just when the defect has occurred. Automated systems are able to provide detailed information about the defect to the operator [8–10]. Components of automated defect detection systems are detailed in the next section. Recently, Ngan et al. [7] reviewed 139 papers for fabric defect detection. They performed a more comprehensive classification of approaches and split them into seven basic groups. Moreover, they categorized as motif-based and non-motif based methods. Yet, the majority of reviewed papers are related to woven fabric defects. Therefore, circular knitting fabric defects were not comprehensively considered in their paper. On the other hand, no informative explanation about the components of image acquisition system was presented. A similar review paper about fabric inspection was previously published by Mahajan et al. [2]. The current defect detection methods were divided into three categories: statistical, spectral and model-based. The main problem of this paper was that it was focused on the uniform fabric textures, but some kinds of fabric have a non-uniform textures. The other problem of [2] was similar to previous review approach [7] that no information about the image acquisition system was given. In this paper, the state-of-the-art fabric defect detection methods in structural, statistical, spectral, model-based, learning, hybrid and comparison approaches, which have satisfactory results are given. The main contributions of our paper are as follows: It presents a more comprehensive categorization of approaches of seven classes (i.e., structural, statistical, spectral, model-based, learning, hybrid and comparison). It also presents a qualitative analysis for each chosen method. Classification accuracy, strengths and weaknesses, utilizable in weaving and knitting fabrics are given for each method. In order to select the components of image acquisition system, it provides the comparative analysis.

2. Fabric defect detection system components

2.1. Camera selection

On-loom fabric image acquisition has some difficulties to acquiring high-quality images. One of the difficulties is the camera selection. Generally, two types of cameras are used for fabric defect detection: area scan and line scan cameras. Line scan camera can obtain images from the fabric surface area at high speeds in the form of lines. Line scan camera must be synchronized to the moving fabric by means of encoder. Camera-encoder interface application is utilized to obtain the true movement direction of the manufactured fabric. This interface provides accurate image-line triggering for line scan camera. Area scan camera may obtain at a more reduced speed, but it acquires the blurred fabric images. In Fig. 2, images obtained from different fabrics captured through area scan camera are shown. In the first column shows the stabile images and the second column shows the moving images. If looked carefully, image of the moving fabric is obtained too blurred to do any transactions on it.

To eliminate the blur in the images obtained by area scan camera, line scan cameras are preferred in the analysis of high-speed objects. Today, line speed cameras with 140 kHz (approximately 140,000 lines in 1 s) can be produced [11]. In Fig. 3, the data package obtained in 1 s from a line scan camera with the rate of 140 kHz, and how these data packages are converted into frames are shown.

As a result, the fact that area scan camera should be used in the analysis of static fabric. In addition, line scan camera should be used in the analysis of moving fabric.

2.2. Lens selection

After the selection of the suitable camera, an appropriate selection of lens is needed. The area to see and field of view with a camera depends on the lens used. Therefore, the most right lens should be chosen taking such values as the working distance, field of view and the size of the sensor. Due to the fact that the sizes of the picture to be formed, its shape and