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Image processing based quality control of the impermeable seams in multilayered aseptic packages

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ABSTRACT

Multilayered aseptic material which guarantees the extended shelf life of liquid foods is turned into an impermeable package by folding packaging machines. Some problems in the machines causes the packages to lose the impermeability property and therefore lead to deterioration of the liquid food. The leak test, which was performed to determine the problem, has been carried out by expert employees. The control process has steps of random selection of the liquid food packages, the opening of it properly, and observing the distribution of the injected ink in the seams by human eye. It is known that this control can cause serious material damage due to the human-based errors. With this study, it was aimed to perform the leak test of seams in multilayered aseptic packages by using a combination of the image processing and classification techniques. Through the data obtained from a real production environment, the experiments were performed and the results were evaluated. As a result, it can be said that the study has a distinctive feature as being the first in its field with its promising results.

1. Introduction

Among developing branches of industry, food production is an important and indispensable part of our life. Liquid food production has a particular importance, because it is a vital consumption requirement for human life. In addition to cost and hygiene of the product, another important subject in liquid food production is packaging process (Dhall, Sharma, & Mahajan, 2010; Nath et al., 2012; Shakerardekani & Karim, 2013). The most important problem in the packaging process was to provide impermeability quality of seams in multilayered aseptic material during the procedure of transforming the material into a package. Despite the developments in packaging technology, unsteady seams caused by different temperature and pressure applications cannot be prevented, and therefore detection right on time of this problem is highly important. These flaws in impermeable seams cause permeating air into the package, and thus spoling of the food. Since determination packages with unsteady seams during storage process may cause more serious financial loss, packaged products are generally controlled at specific intervals in traditional production process in order to determine unsteadies during production. To overcome the problem, the production process is stopped as soon as an unsteady package is determined.

Quality control process of impermeable seams in the liquid food packages is traditionally actualized by the quality control experts. The packages are cut without giving harm to impermeable seams, and a special ink is injected into seams through a syringe. According to the distribution of the ink within the seam, the presence of flaw is tried to be determined visually. In this process, tiredness and inexperience can cause serious pecuniary loss. On the other hand, the problem of not being able to identify unsteady products even in the storage process can cause loss of prestige of manufacturer and also danger for human health because of decayed products.

Several studies have been recently carried out about quality control in industrial production based on computerized systems. As in liquid food production, quality control in other industrial fields usually depends on human eye; and therefore, image processing concept is the most important component of the system for computerized control mechanisms. Because there is almost no study about image processing based quality control of impermeable seams in multilayered aseptic packages, and the general structure of impermeable seams resembles to the fabric seams, our literature also focus on some studies in textile sector. According to used classification and feature extraction methods, some image processing based studies performed for fabric seams are summarized in Table 1.

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As seen in Table 1, several edge detection and segmentation techniques were used in the studies to perform quality control of seams in fabrics by using computerized systems. A computerized determination system including the automatic quality control consists of two stages: image processing and classification. Image processing stage includes image collection, image enhancement and feature extraction steps. Classification process is actualized through a classifier algorithm based on a mathematical model that can also be used in different fields. The classifiers mostly encountered in quality control are linear regression, artificial neural network models, fuzzy logic and genetic algorithms (Faisal, Mohamed, Shareef, & Hussain, 2011; Habib, Faisal, & Rokonuzzaman, 2012; Islam, Akhter, Mursalin, & Amin, 2006; Karayiannis et al., 1999; Kuo & Lee, 2003; Li, Wang, & Cui, 2013; Mitropoulos et al., 1999; Nasira G M, 2014; Saeidi, Latifi, Najar, & Saeidi, 2005). The ultimate goal in studies aiming the computerized quality control is to use suggested system in a real time application. In real time systems, calculation complexity of used computer techniques is expected to be low, and accordingly the response time is expected to be shorter. Therefore, it is a crucial criterion to provide the high classification success through the simple mathematical models with few number of calculations.

In this study, it was aimed to perform the quality control of impermeable seams in multilayered aseptic packages by using various image processing techniques. Because we intend to prove a computer be able to solve every problem by help of definitions from human eye, we used image processing techniques based on only experts' comments. First we prepared images of multilayered aseptic packages as data. These images were taken from two parts of packages: longitudinal seams and transversal seams. Then we used two image processing techniques to extract feature: segmentation and edge detection. Lastly we classified the extracted feature by both linear regression and support vector machine. Image data collection, image processing techniques and classification methods were explained in the second section as subtitles; some evaluations related to the performed experiments were presented in the third section, and a discussion on the study was presented in the fourth section. In the last section, the conclusions related to the study were evaluated.

2. Material and method

2.1. Image data collection

From outside to inside, multilayered aseptic material composes of polyethylene, carton, polyethylene, aluminum folio, and finally two-folded polyethylene. The material is folded properly by the liquid food filling machines and this process is called as sealing. The sealing process provides polyethylene layers to join within proper temperature and pressure adjustments, and by this means the carton package acquires feature of impermeability. The areas where the packages are folded and glued with temperature–pressure adjustment are called by the name of the impermeable seam. The packages have two types of impermeable seams that have physically small differences, as longitudinal and transversal. Because of uninterrupted production, some flaws may occur in the machines. When the flaws changes the conditions of temperature and pressure, it causes manufacturing of the seams without feature of impermeability. This problem is tried to be determined through analyzing the packages chosen randomly from the production line.

In this study which aims to find unsteady seams through some image processing techniques, multilayered aseptic packages filled within liquid food in real production environment for the image data were provided by the factory of DIMES firm in Tokat, Turkey. The most important stage in almost all image processing based studies is collection of images and preparation of them for processing. By this means, the success of the following techniques becomes more reliable. The supplied packages were cut and opened properly by the factory's quality experts, and seams were labelled as steady or unsteady. The datasets prepared to be used in the experiments of the study had two kind of seams: transversal and longitudinal. Moreover, because unsteady longitudinal seams emerge different results in the study, this kind of flaw was analyzed in two categories: HTHP (high temperature and high pressure) and LTLP (low temperature and low pressure). The numbers of package samples used in the datasets are given in Table 2.

Each package used in the experiments had the dimensions of 9 cm $\times$ 5.7 cm $\times$ 19.5 cm and the capacity of 1 liter. In order to have a standard in datasets, whole packages were scanned at the same luminance, contrast, etc. adjustments with Canon N670U scanning device. The images were obtained through scanning the inner surface of packages chosen randomly during the production. Cutting lines on the inner surface of the packages are adjusted so far away from seams that the cutting procedure does not need expertise. Fig. 1 shows inner surface of a sample package.

The locations of transversal and longitudinal seams are marked on the image presented in Fig. 1. Then transversal and longitudinal seams were seperated for the data cluster. The transversal and longitudinal seams prepared for the datasets were presented in Fig. 2.

The steady transversal (a) and longitudinal (b) impermeable seams presented in Fig. 2 were created at average 250–280 °C temperature value and 2,5–3 bar pressure. The temperature values can vary between 10 and 20 °C according to the seasonal conditions. Three samples marked as unsteady by the experts are presented in Fig. 3.

In Fig. 3a, because the required temperature and pressure levels could not be reached, a specific dullness occurred around the seam. We calls this condition as high temperature and high pressure

Table 1
Feature extraction methods and classifiers used in the study.

Study	Feature extraction methods	Classification techniques
Conci and Proença (2000)	Sobel edge detection and thresholding	Linear Regression
Eldessouki and Qashqari (2014)	Fourier transform	Artificial neural network
Habib et al. (2012)	Genetics algorithm	Artificial neural network
Islam et al. (2006)	Thresholding	Artificial neural network
Jasper and Potapalli (1995)	Sobel edge detection, Wavelet and Fourier transforms	Artificial neural network
Karayiannis et al. (1999)	CONE filter and thresholding	Artificial neural network
Kuo and Lee (2003)	Smoothing filters and thresholding	Artificial neural network
Li et al. (2013)	Gaussian Filter	Fuzzy Logic
Mitropoulos et al. (1999)	CONE filter and thresholding	Artificial neural network
Nasira and Banumathi (2014)	Median Filter and thresholding	Artificial neural network
Raheja, Kumar, and Chaudhary (2013)	GLCM and Gabor Filter	Artificial neural network
Saeidi et al. (2005)	Wavelet and Fourier transforms, Gabor filter	Artificial neural network