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Design, development and performance evaluation of an automatic control system for rice whitening machine based on computer vision and fuzzy logic

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ABSTRACT

The objective of this study was developing an intelligent automatic control system (ACS) based on machine vision and fuzzy logic techniques to control the performance of rice whitening machines. The developed ACS consisted of two main parts, namely hardware (including sampling unit, kernel singulation unit, image capturing unit, processor (computer), discharge pressure control unit and data acquisition unit), and software (including image processing, fuzzy inference and central control units). Two important qualitative indices, degree of milling and percentage of broken kernels, were considered as input variables and the level of pressure on the discharge section of the whitening machine was selected as the output variable in the fuzzy inference unit. Results of the evaluations indicated that the developed ACS had 89.2% accuracy in determining the desired working conditions for the whitening machine. The total time of each monitoring round was, on the average, equal to 14.73 s, of which 6.4 s was devoted to kernel sampling and transporting the samples into the imaging chamber, 7.33 s for taking three images from the kernels, processing the captured images and executing the fuzzy inference process, and the remaining 1.5 s for making the adjustments in the level of pressure in the mechanism. Based on this information and in contrast to the corresponding time spent by the human operator to perform a similar process, it was revealed that the performance speed of the ACS was, on average, 31.3% higher than that of the human operator. Evaluation of the samples obtained from the discharge section of the rice whitening machine at different stages of the control process showed that the decisions made by the developed ACS during the control process resulted in a satisfactory improvement in the quality of the output product.

1. Introduction

Based on Food and Agriculture Organization of the United Nations (FAO) estimates, the world population will increase from 7 billion in 2015 to more than 9 billion in 2050 (FAO, 2015). In other words, within 35 years, there will be one-third more hungry population in the world which must be supplied with food. Most of this growth rate is related to the developing countries, which are situated in Asia and Africa. According to these statistics, one of the main challenges facing human societies, especially in the agricultural sector, is how to feed this growing population. In the meantime, with increasing rural migration to urban areas, which results in a reduction of labor force in the agricultural sector, the challenge of providing food for future generations of mankind will become more highlighted. One of the ways to overcome the predicaments associated with the reduction of labor force in the agricultural sector, is relying on mechanized agriculture, that is, generally defined as supplementing the labor force with automated machines in agricultural production systems. The most fundamental issue in working with each type of machine is how to control the machine performance in order to achieve the desired quality of the final product. Generally, quality is defined as the sum of all favorable features in a product that makes it acceptable to consumers. Food quality monitoring often involves assessment of characteristics such as appearance, texture, smell, and taste,

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which can be determined using human inspectors or automatic equipment (Shewfelt and Bruckner, 2000). Experience has shown that human inspection can be easily deluded and is accompanied with high costs, unpredictability of the food production, and variability of results. This highlights the need for objective assessment systems in processing sector.

Recently, automatic inspection systems, based on new technologies such as computer vision, NIR spectroscopy, electric nose, and artificial intelligence have been introduced for the sensory analysis of agricultural products especially food stuff. Computer vision systems have been demonstrated to be useful in quality monitoring and measurement of different agricultural (Jayas et al., 2007; Patel et al., 2012) and food products (Kondo, 2010). These systems present the possibility of automatic grading of food products using standardized techniques and consequently, eliminate tedious human inspection operations (Fang et al., 2014). Such systems are often implemented with an emphasis on nondestructive assessment of product quality (Davies and Sun, 2012; Fan et al., 2013; Wu and Sun, 2013). In order to achieve more precise decision-making in control processes, the interaction with a knowledge database at all stages of the process is essential and is considered an integral part of the computer vision system (Zareiforoush et al., 2015b). The performance and efficiency of an intelligent decision making system depends on the provision of a complete knowledge base. Neural networks, genetic algorithms, and fuzzy logic are some of the techniques for building knowledge-base algorithms for computer vision systems and have been successfully utilized with computer vision in the food industry (Omid et al., 2013; Shiddiq et al., 2011; Song, 2014).

One of the important sectors for application of automatic intelligent systems in the food industry is cereal production. Cereal grains are often damaged by the working parts of agricultural machinery. Among the cereals, rice (*Oryza sativa* L.) is one of the major commercial grains worldwide, along with corn and wheat. The most important difference between rice and other cereal crops is the economic and qualitative aspects of its production. Rice is preferably consumed as whole kernels. The economic value of the dried product strongly depends on the proportion of unbroken kernels. Broken kernels are typically worth approximately 50% (or even less than) the value of undamaged rice (Siebenmorgen et al., 2009). This points to the importance of rice quality monitoring compared to other cereal crops.

In order to obtain white rice from paddy, after harvesting, several operations including threshing, handling, de-husking, milling and whitening are carried out on the paddy grains. If the equipment used in the various mentioned operations are not properly adjusted, excessive rice losses in the final product may occur (Zareiforoush et al., 2010). During rice milling processes, in which paddy hull and bran layer are removed from brown rice, occurrence of mechanical damage due to the intensive forces and stresses involved is more probable compared to other operations (Payman et al., 2014). Generally, in rice mills, due to the lack of an uninterrupted on-line measurement technique, product quality is manually checked every 1–2 h. Traditional quality inspection by human operators is associated with many sources of faults which may result in high losses in the final product. It was hypothesized that the amount and intensity of damage to the final product in rice mills can be reduced using an intelligent automatic control system that this would be suitable for rice mills. Hence, the objective of this study was to control the performance of a rice whitening machine by developing an intelligent automatic control system (ACS) based on machine vision and fuzzy logic.

2. Materials and methods

2.1. Rice whitening machine

Considering the high capacity of commercial rice whiteners (more than 3 tonnes per hour) which require large amounts of rice, a medium-scale abrasive type rice whitening machine with a working capacity of 300 kg/h (Model KHP-300, Khosro-Parviz Co., Iran) was constructed for conducting the tests. This would also reduce the high probabilities of errors usually associated with experiments using large scale models.

2.2. Automatic control system

The developed ACS is a closed-loop control system in which the information on qualitative indices of rice grains is acquired through sampling from the discharge section of the whitening machine. The performance of the machine is modified through comparing the actual condition with the set point. Block diagram of the developed ACS is shown in Fig. 1. In this system, first a certain amount of the product discharging from the whitening machine is sampled. Then, the sampled kernels are singulated and transferred to the imaging unit. In this unit, images of the samples are captured and the acquired information from image analysis is delivered to the processing and inference unit. The information fed into the processing unit is compared to previously prepared information which have been. Consequently, a command signal based on the result of inference is generated and sent to the operating parts in order to improve the machine performance. The

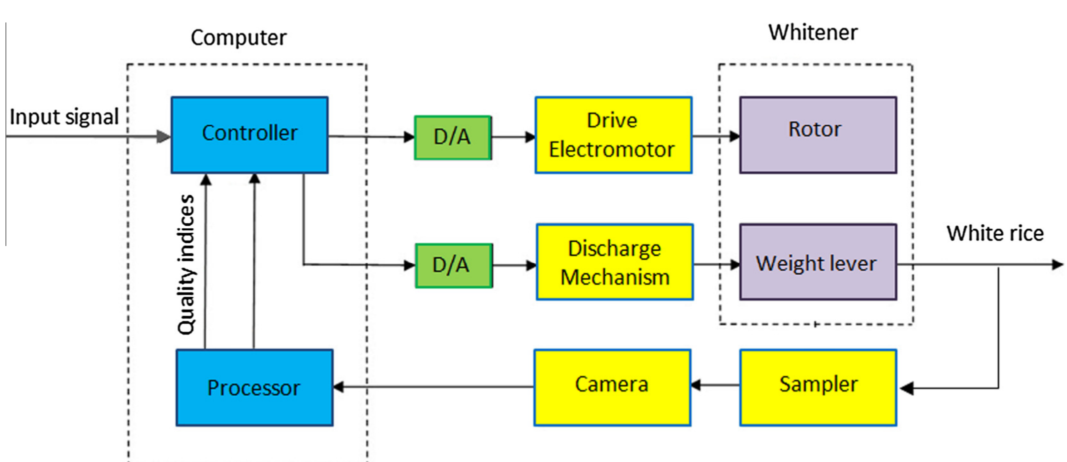

Fig. 1. Block diagram of the automatic control system.