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A hybrid intelligent approach based on computer vision and fuzzy logic for quality measurement of milled rice

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ABSTRACT

In this research, a fuzzy inference system (FIS) coupled with image processing technique was developed as a decision-support system for qualitative grading of milled rice. Two quality indices, namely degree of milling (DOM) and percentage of broken kernels (PBK) were first graded by rice processing experts into five classes. Then, images of the same samples were captured using a machine vision system. The information obtained from the sample image processing was transferred to FIS. The FIS classifier consisted of two input linguistic variables, namely, DOM and PBK, and one output variable (Quality), all in the form of triangle membership functions. Altogether, 25 rules were considered in the FIS rule base using the AND operator and Mamdani inference system. In order to evaluate the developed system, statistical performance of the FIS classifier was compared with the experts' judgments. Results of analysis showed a 89.8% agreement between the grading results obtained from the developed system and those determined by the experts.

1. Introduction

Rice (*Oryza sativa* L.) is one of the major commercial grains worldwide, the economic value of which strongly depends on the proportion of unbroken kernels. In the rice processing industry, the quality of final product depends on several sensory properties. Among the later, visual properties are more important because they can significantly affect the choice and preferences of consumers. Commonly, there are two major visual indices for determining the quality of rice kernels in the processing industry namely, degree of milling (DOM) and percentage of broken kernels (PBK). Generally, in rice mills, due to unavailability of continuous on-line measurement methods, quality grade of the product is monitored visually by experienced operators at 1–2 h intervals [1]. This means that the operator, based on his experience and proficiency with the processing machinery, assesses the quality of the product by mere visual inspection of the machine output and making the required adjustments. In this regard, development of automated systems which can mimic the expert operators' decision-making process would be quite beneficial for quality grading of the product. Nevertheless, such an automated quality grading of rice kernels is not an easy task.

Soft computing is an innovative method for development of intelligent systems which has attracted increasing interest by the scientific community during the past few decades. Generally, in order to solve real world computation problems, a combination of computational techniques is preferred to the exclusive use of single methods. One such combinative method is neuro-fuzzy system [2]. Since its inception, the theory of fuzzy sets has advanced in a variety of ways in many disciplines. Applications of this theory can be found, for example, in artificial intelligence, computer science, medicine, control engineering, decision

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theory, expert systems, logic, management science, operations research, pattern recognition, and robotics. Fuzzy logic may also be useful for descriptive systems, those that fall somewhere between hard systems and soft systems, such as biology and agriculture [3].

In addition to fuzzy control, computer vision technology has also being used widely for design of intelligent control systems [4,5]. Computer vision is the science that deals with object recognition and classification by extracting useful information about the object from its image or image set. It is a branch of artificial intelligence combining image processing and pattern recognition techniques. The major tasks performed by a computer vision system can be grouped into three processes: image acquisition, image processing, and object recognition. Different characteristics of the objects are extracted and final decisions are made using various image processing algorithms and pattern recognition techniques, respectively. Computer vision-based inspection is already in commercial use in automotive, electronics, and other industries. Many of the industrial objects being inspected are defined based on size, shape, color, and texture. Agricultural or biological objects, including grain kernels, on the other hand, are of variable size, shape, color, and texture. In addition, these features may vary from year to year, by growing region within a year, and even over a single growing season [6].

In recent years, scientists and researchers have attempted to design and develop automatic systems based on computer vision and artificial intelligence for quality evaluation and grading of rice. Sansomboonsuk and Afzulpurkar [7] developed shrinkage algorithms to extract features of rice kernels in two forms of point and line touching kernels. Fuzzy logic method was utilized to organize and classify the kernels. Experimental results found that the algorithms perform satisfactorily in evaluating the percentage of broken rice with overall accuracy of 92%. Shiddiq et al. [8] suggested an Adaptive Neuro-Fuzzy Inference System (ANFIS) in which the relationships between rice color characteristics and its quality grade can expressed in the form of "if-then" fuzzy rules. Some authors have attempted to incorporate vision techniques into metaheuristic classification algorithms and optimization methods for identifying rice kernels of different varieties. Liu et al. [9] applied a digital color image analysis algorithm based on morphological features and artificial neural networks to identify six varieties of rough rice seeds. Guzman and Peralta [10] proposed the combination of a machine vision system and artificial neural networks for automatic identification of 52 varieties of rice grains belonging to five varietal groups of the product in the Philippines. In a research, Mousavi Rad et al. [11] utilized Imperialist Competition Algorithm (ICA) to select the best feature set for classification of seven Iranian rice varieties. The optimal features were also selected using Genetic Algorithm (GA) and its performance was compared with the ICA method. Results indicated that the ICA-based method provided better classification performance than the GA technique. Chen et al. [12] showed that head rice and broken rice could be effectively identified by Least Squares Support Vector Machines in a machine vision-based inspection system. Similarly, MousaviRad et al. [13], Fayyazi et al. [14], Prajapati and Patel [15], Gujjar and Siddappa [16], Kaur and Singh [17], Shantaiya and Ansari [18], Prajapati and Patel [15], and Silva and Sonnadara [19] for classification of different rice varieties using and multi-class SVM and artificial neural networks.

A review of the literature shows that Fuzzy-logic-based methods can effectively represent the semantics of human assessment in sensory analysis and subjective decision making processes [20–25]. Nowadays, quality assessment of milled rice is done in markets based on the human experts' judgments. Hence, the objective of this study was to develop a hybrid intelligent system based on computer vision and fuzzy logic for representing human expert's behaviour in qualitative grading of milled rice.

2. Materials and methods

2.1. Sample preparations

The laboratory analyses were performed in the Rice Research Institute of Iran (RRII). The evaluated rice variety, Hashemi, is one of the common varieties of rice in north of Iran [26]. This variety is categorized as long kernel rice according to the standard provided by the Institute of Standards and Industrial Research of Iran (ISIRI, 2012). Rice moisture content was determined by means of a digital moisture meter (GMK model 303RS, Korea) to be 11–13.5% (w.b.) for the evaluated samples.

2.2. Fuzzy inference system

The fuzzy inference system (FIS) was implemented in the Fuzzy toolbox of MATLAB version R2013a (MathWorks, 2013). The first step in each FIS implementation is to define the name and number of the variables involved in the inference and decision-making processes. These parameters are initially in the form of crisp variables which are then converted to fuzzy values using fuzzifier functions. The fitting characteristics for the FIS variables were assigned based on a survey which was conducted in the modern rice mills of the area. The aim of this survey was to acquire human expert's knowledge in quality evaluation of rice. Experts' knowledge was considered for the determination of each membership function (MF) name, range and also MFs' intervals. Based on the investigation, two quality indices namely, degree off milling (DOM) and percentage of broken kernels (PBK) were considered as the FIS inputs and the quality of the product was selected as the only output of the FIS. In order to design the fuzzifier functions, which are also known as MFs, first the range of variation for the input variables should be defined. It is also necessary to determine the appropriate name, number and variation range for each of the MFs of the FIS variables. Results of the investigation in rice mills revealed that the expert opinion on both quality indices can be expressed in the form of five crisp variables namely, Very Low (VL), Low (L), Medium (M), High (H), and Very High (VH). It was also found that the experts opine on the product quality in the form of five linguistic variables including Very Bad (VB), Bad (B), Medium (M), Good (G), and Very Good