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Learning techniques used in computer vision for food quality evaluation: a review

Cheng-Jin Du, Da-Wen Sun *

FRCFT Group, Department of Biosystems Engineering, University College Dublin, National University of Ireland, Earlsfort Terrace, Dublin 2, Ireland

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Abstract

Learning techniques have been applied increasingly for food quality evaluation using computer vision in recent years. This paper reviews recent advances in learning techniques for food quality evaluation using computer vision, which include artificial neural network, statistical learning, fuzzy logic, genetic algorithm, and decision tree. Artificial neural network (ANN) and statistical learning (SL) remain the primary learning methods in the field of computer vision for food quality evaluation. Among the applications of learning algorithms in computer vision for food quality evaluation, most of them are for classification and prediction, however, there are also some for image segmentation and feature selection. In this paper, the promise of learning techniques for food quality evaluation using computer vision is demonstrated, and some issues which need to be resolved or investigated further to expedite the application of learning algorithms are also discussed.

Keywords: ANN; Classification; Computer vision; Decision tree; Feature selection; Food; Fuzzy logic; Genetic algorithm; Image segmentation; Learning; Prediction; Quality evaluation; SL

1. Introduction

Quality is a key factor for modern food industry because the high-quality of product is the basis for success in today's highly competitive market. In the food industry, the quality evaluation still heavily depends on manual inspection, which is tedious, laborious, and costly, and is easily influenced by physiological factors, inducing subjective and inconsistent evaluation results. To satisfy the increased awareness, sophistication and greater expectation of consumers, it is necessary to improve quality evaluation of food products (Brosnan & Sun, 2004). If quality evaluation is achieved automatically, production speed and efficiency can be improved in addition to the increased evaluation accuracy, with an accompanying reduction in production costs (Sun & Brosnan, 2003a).

As a rapid, economic, consistent and even more accurate and objective inspection tool, computer vision systems have been used increasingly in the food industry for quality evaluation purposes (Sun, 2000). The application potential of computer vision to the food industry has long been recognised (Tillett, 1990). The food industry ranks among the top 10 industries using computer vision technology (Gunasekaran, 1996), which has been proven successful for the objective and non-destructive quality evaluation of several food products (Timmermans, 1998). Being an objective, rapid and non-contact quality evaluation tool, computer vision has been attracting much R&D attention from the food industry, and rapid development has been increasingly taking place on quality inspection of a wide range of food products (Sun, 2004).

* Corresponding author. Tel.: +353 1 716 5528; fax: +353 1 475 2119.
E-mail address: dawen.sun@ucd.ie (D.-W. Sun).
URL: http://www.ucd.ie/refrig.

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Combined with an illumination system, a computer vision system is typically based on a personal computer (PC) in connection with electrical and mechanical devices to replace human manipulative effort in the performance of a given process. Illumination is an important prerequisite of image acquisition for food quality evaluation. The quality of captured image can be greatly affected by the lighting condition. A high quality image can help to reduce the time and complexity of the subsequent image processing steps, which can decrease the cost of an image processing system. Different application may require different illumination strategy. Novini (1990) reported that most lighting arrangement could be grouped as one of the followings: front lighting, back lighting, and structured lighting. For image processing algorithms, software implementation on a PC allows for rapid development, debug, and test. However, as image sizes grow larger and algorithms become more complex, the speed will be slower and cannot satisfy the requirement of high speed in real-time systems. Conversely, hardware implementation offers much greater speed than software one. There are several viable options for hardware implementation of image processing algorithms, such as application specific integrated circuits (ASICs), digital signal processors (DSPs), and field programmable gate arrays (FPGAs). Although the speed can be improved by hardware implementation, one must consider the increase in development cost for creating a custom hardware design. Therefore, hardware designers usually use some sorts of PC programming environment to implement a design to verify functionality prior to a lengthy hardware design. This paper will focus on the software part of learning techniques used in computer vision for food quality evaluation. The illumination system and hardware implementation of image processing algorithms required for a computer vision system will not be discussed in details here. Interested readers can refer to papers and books on the topic for details (Gunasekaran, 1996; Jóźwiak, Ślusarczyk, & Chojnacki, 2003; Moore, 1995; Perkowski, Jóźwiak, Foote, Chen, & Al-Rabadi, 2002; Russ, 2002).

During the last decade, considerable research effort has been directed at developing learning techniques for food quality evaluation. Goyache et al. (2001) advocate the application of artificial intelligence techniques to quality assessment of food products, which can help to extract operative human knowledge from a set of examples, to conclude interpretable rules for classifying samples, and to ascertain the degree of influence of each objective attribute of the assessed food on the final decision of an expert. Corney (2002) introduced intelligent systems and highlighted their use in all aspects of the food industry.

Learning technique is one of the essential features for food quality evaluation using computer vision, as the aim of computer vision is to ultimately replace the human visual decision-making process with automatic procedures. Computer vision tries to clone human behaviour of performance in colour, content, shape, and texture inspection (Domenico & Gary, 1994). Backed by the powerful learning systems, computer vision provides a mechanism in which human thinking process is simulated artificially and can help human in making complicated judgments accurately, quickly and very consistently over a long period (Abdullah, Guan, Lim, & Karim, 2004). Learning techniques can be employed to learn meaningful or nontrivial relationships automatically in a set of training data and produce a generalisation of these relationships that can be used to interpret new, unseen test data (Mitchell, Sherlock, & Smith, 1996). Therefore, using sample data, a learning system can generate an updated basis for improved classification of subsequent data from the same source, and express the new basis in intelligible symbolic form (Michie, 1991). Nevertheless, there is a definite need for research dealing with the combination of computer vision and learning techniques for food quality inspection (Vízhányó & Felföldi, 2000).

The aim of this paper is to investigate the recent applications of learning techniques in computer vision for food quality evaluation, and to illustrate their role and discuss the remaining challenges. Fig. 1 shows the general learning system configuration used in computer vision for food quality evaluation. As indicated in Fig. 1, using the image processing techniques, the images of food products are quantitatively characterised by a set of features, such as size, shape, colour, and texture. In literature, a variety of different methods have been developed to measure size, shape, colour, and texture features, which have been reviewed elaborately by Du and Sun (2004). These features are objective data used to represent the food products, which can be used to form the training set. Once the training set has been obtained, learning algorithm extracts the knowledge base necessary to make decision of unknown case. Based on the knowledge, intelligent decision is made as output and fed back to the knowledge base at the same time, which generalises the way that inspectors use to accomplish their tasks. Among the applications where learning techniques have been employed for building knowledge base, artificial neural network (ANN) and statistical learning (SL) are the two main methods. In the mean

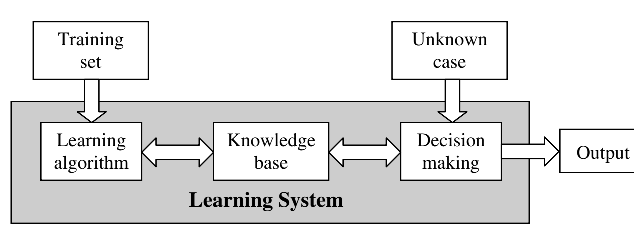

Fig. 1. The general configuration of machine learning system.