A New Approach for Automatic Quality Control of Fried Potatoes Using Machine Learning

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Abstract— **Frying of potatoes causes some changes in their microstructures. By studying these changes we have presented quite suitable features for automatic analysis of microscopic images taken from fried potatoes, and have also introduced a new mechanism based on machine learning for automatic quality control of fried potatoes. Experimental results show that the presented structure may well be used for controlling the quality of related products.**

Index Terms— **Neural networks, Machine Vision, Texture recognition, Quality control, Potato microstructures.**

I. Introduction

One of the methods for preparing food is frying. This method is widely used throughout the world and nearly everywhere such fried food is controlled in terms of quality and health. One food material that has attracted numerous studies to its frying in the past is potato. Our goal here is to let the analysis and qualitative control of fried potato be done algorithmically; or in other words, automatically and by a machine. To that purpose we shall first review the works of the past in order to extract suitable features for machine vision. In [1] there is an analysis of the microstructures of potatoes while being fried. In this paper it has been shown that by increasing temperature from 20°C to 150°C the potato cells change their shapes and their circularity decreases. Also, the starch granules inside the cells swell and gelatinize, and expand to whole volume. In this paper it has been shown that after gelatinization, the starch of the cells get dehydrated and then shrink. In [2] and [1] it has been expressed that studying the frying of potato cells clearly shows that the starch granules constantly swell and expand throughout the cell in a certain temperature (e.g. 60°C to 70°C) by the intercellular water. In [3] it has been said that after this phase, steam bubbles crack and pass through the pores in the cell walls and find their way into the oil interface. In [4] it has been shown that before being dehydrated in higher temperatures, the swollen starch granules remain like a compact mass pressed on the outer cell walls. In [3] the rate of penetration of oil in the potato during frying has been estimated by the changes in the tissue surface and X-ray photography. There are many more papers that have worked on fat uptake, e.g. [8], [5], and [6]. And some works on quality control of fried potatoes used classification methods and neural network such as [10], [11]. In [10] there is an approach to classify the potato chips using pattern recognition from digital color macroscopic images. In [9], analysis of digital color macroscopic images of fried potato chips were combined with parallel LC-MS based analysis of acrylamide in order to develop a rapid tool for the estimation of acrylamide during processing. [11] that uses image analysis and artificial neural network for quality control of potatoes in chips industry and [12] that includes texture analysis of fried potato.

According to what was said above, we rewrite the process of microscopic changes in potatoes during frying: (1) raw potato cell, (2) swelling of starch granules inside the cell, (3) gelatinization of swollen starch granules, and (4) shrinkage of potato cells. The algorithm we have presented enables the machine to automatically determine and figure out in which state the potato microstructures are, and whether or not the fried potato is in its best form in terms of quality. The overall structure of the paper is such that we first describe the proposed structure for separating the tissues and inferring the results, then we point out to the equipment being used and finally explain the results of implementation and assessment of the algorithms.

II. VARIETIES OF TEXTURE SEEN IN THE IMAGES

A sample of the images taken from fried potatoes is shown in time order in Figure 1. In Figure 1.a the cells of raw potato are seen. Figure 1.b shows a swollen texture which has been made due to swelling and expanding of starch granules. Figure 1.c presents a gelatin-like texture; and Figure 1.d shows a shrunken texture. Most taken images only include a certain texture, and only in some images are the two swollen and gelatinized textures seen together (Figure 3). According to what was said above, the images are classified within these 5 class: (1) images including the cell texture, (2) images including swollen textures, (3) images including gelatinized texture, (4) images including shrunken texture, and (5) images including gelatinized and swollen texture at the same time. In class 3 image there are some transparent to dark brown colors.

It should be added that the texture titles and their correct naming is not important, what is significant is that the machine should be able to separate and distinguish these 4 textures which are made during frying of the potatoes.

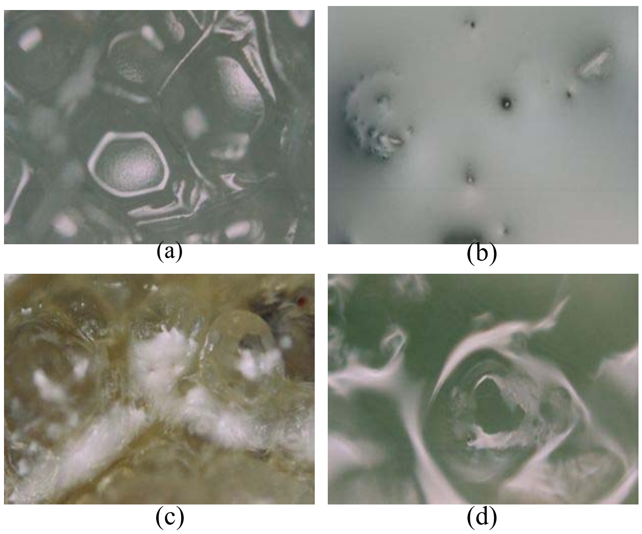

Figure 1 varieties of texture seen in the images: (a) a sample of class 1, (b) a sample of class 2, (c) a sample of class 3, (d) a sample of class 4.

A. Automatic Recognition of Image Class

One of the interesting features in images of classes 1, 2, and 4 is that the apparent difference of the images in HSI space with its Gray-level is too small; and this means that the color factor has the least presence in them. To formulate the amount of colorfulness of the images, we should first calculate the histogram of the images in HSI space. It is seen that the standard deviation in the histogram of Hue matrix of the images of classes 1, 2, and 4 is more than the standard deviation of the histogram of H element in images of classes 3 and 5. This is obvious because in images 1, 2, and 4 there are various intensities for the two main colors of black and white, but in images of class 3 or 5 there is a spectrum of the main colors (Figure 2). To distinguish between the images of classes 1, 2, 4 we pay attention to this point that the details are few in images of class 2. Also, the details of image of class 1 are more than the details of image of class 2, and the details of image of class 4 are more than the details of image of class 1(Figure 1). Therefore, counting of edges in the images may be a good criterion for distinguishing them. To distinguish the images of class 3 from class 5 we use the point that was mentioned above, and that being existence of few details in swollen textures. Thus the image details in classes 5 are less than image details in class 3 because the texture is swollen. Pay attention that the details are too many in images including gelatinized textures (Figure 1.c) and the growth of swollen texture in it (i.e. class 5) decreases the amount of details (Figure 3). Figure 4 shows the pattern for distinguishing among various classes of images along with the technique being used.

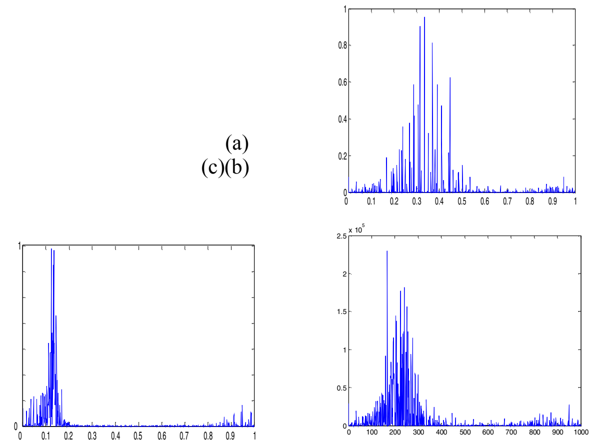

Figure 2 Histogram of hue: (a) for figure1.a (b)for figure 1.b (c) for figure 1.c(we can use the standard deviation in the histogram of Hue matrix of the images To distinguish the images of classes 1, 2, and 4 from classes 3, 5)

B. Separating gelatinoid and Swollen Textures in Class 5 Images

As said earlier, class 5 images include both gelatin-like and swollen tissues. To extract the information related to the extent of their presence in an image we have to segment the images of this class based on the 2 types of texture. As said before these two types of textures are differentiated based on the fact that the apparent difference of the swollen texture in HSI space with gray-level mode is very small, and this indicates that various colors are not present in swollen textures; while gelatinized textures, unlike swollen ones, include various and diverse colors. This means that the standard deviation in the histogram of the Hue element of swollen textures is higher than the standard deviation in the histogram of Hue element for gelatin-line textures. To use this feature we first divide the image into small equal blocks (e.g. 0.04 of the image size) and then calculate the standard deviation from the histogram of the hue element in each block (Figure 5). Then we will have a matrix. Now we divide the matrix elements into two groups by aid of the neural network (this dividing is done by using the self organization neural network). The elements in the matrix are representatives of blocks in the main image, and elements in the same group of the matrix show that the related blocks of the main image have the same texture type. It is clear that the group in which the standard deviation of the histogram of Hue element is higher points to the swollen texture.

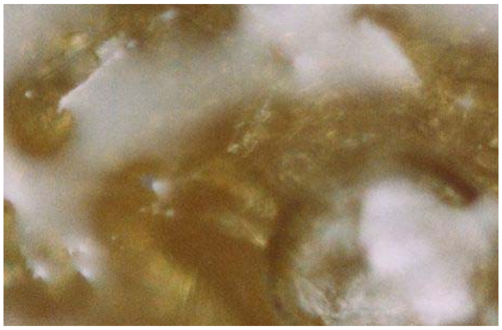

Figure 3 one sample images including both gelatinized and swollen texture at the same time.

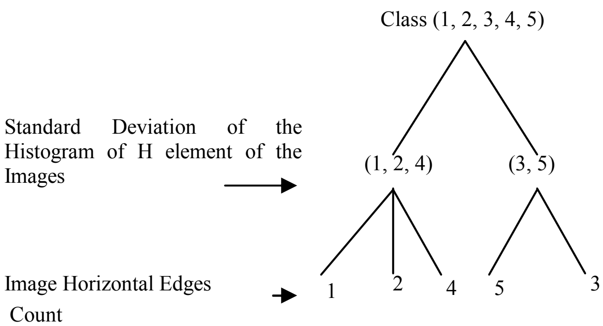

Figure 4 the pattern for distinguishing among various classes of images (the used way was shown by the point.

III. AUTOMATIC QUALITY CONTROL OF FRIED POTATO

Up to the end of the previous stage the machine has successfully collected the information related to type of image and extent of gelatinization of swollen textures, which show the phases of change progress. To answer the question "Is the fried potato in its best quality or not?" we should present the machine in one learning level with some microscopic images of fried potatoes with best quality. The machine applies all of the above algorithms to them and extracts: (1) the class number of microscopic images, (2) extent of gelatinization of swollen textures of class 5, and (3) the mean of the three H, S, I elements (H_{mean}, S_{mean}, $\bar{I}_{mean}$) for class 3 images, and keeps them in a database as the learning sample. We used the perceptron neural network with 5 inputs and 2 outputs(one of them for good class and another for bad class) and 5 neuron in it's hidden layer (One layer) for classification. Only for those fried potatoes the answer is yes that after leaning phase and feature extraction, the learned neural network, classify them in the good class.

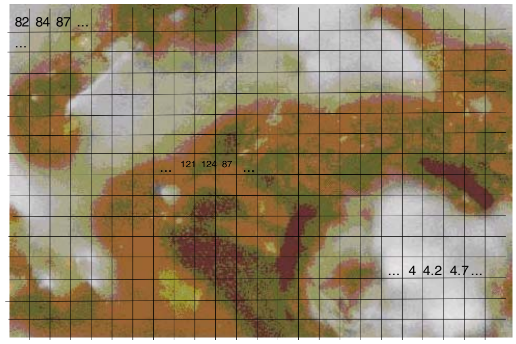

Figure 5 the standard deviation in the histogram of the hue element in each block(the sample values must multiply by 0.0001).

IV. EVALUATION

The materials used in this work are as follows:
Potatoes were obtained from a local supplier and were cut in cylindrical shapes having diameters of 12 mm and lengths of 40 mm and after frying process samples were obtained from parenchymatous region of cylindrical potatoes. Samples were consecutively fried using vegetable oils that are common in Iran. The sampling has been done at temperatures of 80° to 180°C in time intervals of 3 minutes. The potatoes have been fried by using a gas cooker and by direct heating. Photographing the samples has been done with a "Olympus BX60" optical microscope with its integral camera and adaptor and with magnitudes of 100 and 200. All presented methods have been written and tested on Matlab R2006a.

We have put the features extracted from more than 30 images with sizes of 2150×3270 taken from best fried potatoes in the database as learning samples, and have conducted the tests and assessments of the presented mechanism and algorithms for them on more than 60 microscopic images. We used the feed forward propagation algorithm and by supervisor classification for learning faze. The results are shown in Table 1, 2, and 3. Table 1 related algorithms presented for recognizing the type of microscopic images. The size of the blocks mentioned in 1.2 section was 0.01 of the image size. In Table 2 the row entitled "Total" relates to the sum of blocks including gelatin-like or swollen textures in all class 5 images. Table 3 shows the performance evaluation for the defined goal. Row 2 relates to the number of the samples recognized to meet the desired quality.

Table 1 recognizing the class of microscopic images

	Class1	Class2	Class3	Class4	Class5
Total #	14	15	8	17	13
Correct	14	14	7	15	12
Accuracy	100%	93%	88%	88%	92%

Table 2 proposed algorithm for texture recognition

	Blocks including gelatinized textures	Blocks including Swollen textures
Total #	42	98
Correct	38	91
Accuracy	90%	93%

Table 3 performance evaluation for quality control

	Potatoes with desirable quality	Potatoes with undesirable quality
Total #	12	24
Automatic count of items with desirable quality	12	2
Accuracy	100%	92%

V. CONCLUSION

In this paper, we proposed a new method on microscopic images of fried potato. The algorithm can answer this question: "Is the fried potato in its best quality or not?" For answer the question, first the machine extracts the predefinition features from the sample microscopic images (Learning samples) and then machine uses neural network for by supervisor classification, We can use that neural network for detecting the good samples. The proposed mechanism can be used for chips and other related products.

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