Grain Classification and Grading Based on Fourier Descriptor

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ABSTRACT
Visual inspection is commonly used to assure food quality. For grain quality it is desired to automate the inspection process for consistency, accuracy and speed. Thus, a method for automating food inspection is proposed to classify good quality grains and defective grains. This paper presents a method for model-based classification which uses Fourier descriptor.

Keywords
Image Processing, Fourier Descriptor, Classifier, Grains

1. INTRODUCTION
High quality food products had always been the goal of many food companies. Careful handling is observed in planting, harvesting, processing, manufacturing and trading of these products to make sure that its value would not depreciate. No matter how careful handling of these products is done, damages couldn’t be a hundred percent avoided. Damages could be easily identified on most food by examining their shape. The soundness of most food products depends on their shape and damages to them are manifested by deformation. This includes products such as grains. Unlike other products, shapes of grains are hard to observe since they are small. It requires careful visual inspection by well-trained humans and this process is actually slow. Through technological developments, automation of different processes like this is now possible. In this study, an automation of visual inspection of grain shapes will be implemented to categorize broken grains and whole grains.

Machine vision is becoming a popular replacement for manual inspection. Reason behind this is that a machine, unlike humans doesn't get tired fast, it is most of the time more consistent and accurate, and observations are objective rather than operator's subjective view. Many studies about machine vision system and its power to automate visual inspection of food products had been made. System of this kind usually uses visual information of products like color, shape and texture. Among this information, this study would focus on shape for it is a very important feature of grain product that is also important to human perception.

Techniques had been developed for an effective classification and grading of food products using machine vision. Different feature extractor or descriptor and classifier had been used. Laszlo [2] is able to model the human visual inspection of grains. He uses visual information categorized as shape features, color features, and surface pattern. Liu et al. [3] developed an algorithm to identify varieties of rice seed using shape and color features. They used a neural network as classifier to identify the correct variety of a particular rice grain. Ding et al. [1] developed an automated food shape inspection system. This system has a feature extraction stage that uses a statistical model-based (SMB) feature extractor and a multi-index active model-based (MAM) feature extractor, and a classification stage where a minimum identifier (MIZ) machine learning classifier is developed. They successfully extracted shape indices as input into the classifier. Liao et al. [3] developed a neural classifier based machine vision for an on-line classification of broken and whole corn. They based their classification from shape features.

In [5] a study of different shape analysis method is presented. Different shape analyses are classified and grouped based on the use of boundary or interior, and based on the type of result (numeric or non-numeric). The four types identified are boundary scalar, boundary space-domain, global scalar and global space-domain. Advantages and disadvantages of each group are also presented.

Based on this study, a boundary scalar technique is chosen for its robustness and translational, rotational and scale invariant. Boundary scalar transform algorithms typically consist of two major steps [5]. First step is to construct a one-dimensional characteristic function of the two-dimensional shape boundary. Second step to describe the shape of the two-dimensional boundary through the one-dimensional characteristic function constructed. Two approaches in describing the shapes can be use. One approach is the use of Fourier transform of the characteristic function and another approach is based on a stochastic process modelling of the characteristic function.

In [6], different shape signatures in deriving a Fourier descriptor are compared. The significance effect of each method in retrieval of image is the standard for comparison. The study shows that centroid distance signature is better than the other three because it captures both local and global features of shape that makes it desirable as shape representation.

The objective of this study is to derive a shape descriptor of grain and develop a model-based classifier that utilizes the descriptor. The Fourier descriptor is chosen because of its invariance to translation, rotation and scale. Since centroid distance signature is proven to work better, it would be used in shape representation.
2. GRAIN CLASSIFICATION

An image of the object to be classified, grain images for this system, is the input to the classifier. From these images, shape descriptors would be derived. Classification will be based on the descriptors. There are actually four major processes that are involved in the development of this grain classifier as shown in figure 1.

![Diagram of image processing steps](image)

Figure 1. Four Major Processes in Implementing the Method

2.1 Image Acquisition

There are many different ways to acquire an image. One example is using a camera, but this would require much time in setting up to achieve balance illumination. To obtain good images, grains are preferred to be scanned using a flatbed scanner. This way, acquiring images will be fast since no much set up needs to be made. This scanned image then needs to be processed.

2.2 Image Processing

The object of interest needs to be extracted from its background. One best way to do this is by thresholding. The colored image will be converted to its binary equivalent labelling the black pixel as preferred to be scanned using a flatbed scanner. This way, four shape signatures are compared where centroid distance function is found significantly better than the other three. This function is adopted in this study. It is expressed by the distance of boundary points from the center of mass given by the formula below:

\[ d(i) = \sqrt{[x(i) - x_c]^2 + [y(i) - y_c]^2} \]

Where \((x_c, y_c)\) is the center of the shape and \((x(i), y(i))\) are the coordinates of the boundary points.

Due to the subtraction of centroid, which represents the position of the shape, from boundary coordinates, the centroid distance representation is invariant to translation [6].

The Fourier descriptor will then be used in shape matching or discrimination. But before applying Fourier transform in centroid distance function, shape must first be sampled to normalize the sizes of the shape descriptor to be matched. The equal arc length sampling method is use to normalize the data. It selects candidate points spaced at equal length along the shape boundary. The space between two consecutive candidate points is given by \(P/K\), where \(P\) is the perimeter of the shape boundary and \(K\) is the number of desired sample points.

Once data are normalized, the discrete Fourier transform can be applied given by the formula below:

\[ FD_n = \frac{1}{N} \sum_{t=0}^{N-1} s(t) \left( \frac{-j2\pi nt}{N} \right), \quad n = 0, 1, ..., N - 1 \]

The coefficients \(FD_n, n = 0, 1, ..., N - 1\), are called Fourier descriptors (FD) of the shape.

Since centroid distance is invariant under translation, therefore, the corresponding FDs are also translation invariant. Rotation invariant of the FDs are achieved by ignoring the phase information and by taking only the magnitude values of the FDs. Scale invariance is obtained by dividing the magnitude values of the first half of the FDs, starting from the second descriptor, by the first descriptor.

\[ f = \begin{bmatrix} FD_1 & FD_2 & \cdots & FD_{N/2} \\ FD_0 & FD_0 & \cdots & FD_0 \end{bmatrix} \]

2.3 Image Description

A shape analysis technique classified under a boundary scalar type will be used in this development. The first step in shape analysis is to represent the data in either of the two ways: use of shape features and use of descriptors. Literature defines shape feature as a simple geometric characteristic or physical quality of the object while a descriptor as a feature sets that represent a specific local or global area. What was used in this study is the Fourier descriptor.

Fourier descriptors are formed by Fourier transformation of shape signatures. In [6], shape signatures are defined as a one-dimensional function that describes the two-dimensional shape boundary. Four shape signatures are compared where centroid distance function is found significantly better than the other three. This function is adopted in this study. It is expressed by the distance of boundary points from the center of mass given by the formula below:

\[ d(i) = \sqrt{[x(i) - x_c]^2 + [y(i) - y_c]^2} \]

where \((x_c, y_c)\) is the center of the shape and \((x(i), y(i))\) are the coordinates of the boundary points.

2.4 Shape Discrimination

Shape discrimination is a method for comparing shapes. It is used when a set of known objects is compared to an unknown object or what is called as model-based comparison. In this research two objects are matched using their Fourier descriptor. Their similarity are measured through the used of Euclidean distance.

\[ ED = \sqrt{\sum_{t=0}^{N} \left| f_m(t) - f_d(t) \right|^2} \]
Where, $f_m$ represents the model FDs and $f_d$ as the data FDs. $N_c$ is the normalized size of the descriptor vector.

3. EXPERIMENT AND RESULTS
Corn kernels is the focus of this experiment since it is largely consumed and marketed in agricultural country like the Philippines and its size is good enough to be observed.
Images of corn kernels are obtained through the use of flatbed scanner. Blue background is chosen because it has a good contrast with the colors of the kernels. Kernels are aligned carefully in a vertical position. Tip cap, as possible, should be placed in the bottom. Sample scanned image of kernels is shown in figure 2.

![Figure 2. Scanned images of corn kernels. The background used was plain blue since it has good contrast with the yellow colored corn kernel.](image)

Scanned images contain many kernels in a single frame. To be able to extract the shape successfully a frame should only contain a single kernel. This is achieved by separating each kernel like what is shown in figure 3.

![Figure 3. Corn images. Three images at the top are samples of whole kernels, while three images at the bottom are samples of broken kernels.](image)

The next step is to separate the kernel from its blue background. The gray, red, green and blue values of the images are observed to see which of these values are distinct between the object of interest and the background. Based on the observation, it was discover that the red and green values are very different in the scope of the object and the blue background. The green component is chosen and was analyzed to determine a fix value threshold. A threshold value is then set to 150. This value is the basis in extracting the object. If value is greater than or equal to 150 color of the pixel is set to black while if the value is less then 150 the pixel is assigned with a white color. This process is called thresholding. Extracted images are shown in figure 4.

![Figure 4. Binary images. This images are results of thresholding the images in figure 3.](image)

This binary image could possibly have noises so noise reduction techniques, binary dilation and binary erosion, are applied. Cleaned binary images are shown in figure 5.

![Figure 5. Cleaned binary images. The boundaries of the binary images in figure 4 are smoothened in preparation for shape analysis.](image)

An eight-connected boundary following algorithm is then applied to the cleaned binary images. Sample boundaries extracted are shown in figure 6.
Distances of each boundary points from the centroid will then be computed. Figure 7 illustrates how this distances are measured.

Figure 7. Transformation of pixel boundary to graph of distances from centroid.

Figure 8 shows a graph of the computed centroid-boundary distances.

Figure 8. Graph of distances(y) plotted for each boundary points(x) for the boundaries in figure 6. The graphs at the bottom corresponding to broken kernels are significantly different from the graphs of whole kernels.

The model-based comparison was able to classify 91% whole kernel but only 28% broken kernel. There was total of 22% misclassification.

4. CONCLUSION
This research proposed a method in classifying and grading grains. An existing method use for shape retrieval was modified and adopted in the development of the classifier. This method was proven to successfully identify whole kernels well than identifying broken kernels. But this could still be improved. Future experiment could increase the number of models to better discriminate the kernels.

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6. REFERENCES
[1] Ding K. and Gunasekaran S., “Shape feature extraction and classification of food material using computer vision”.