# Machine-Vision-Based Cash Register System for a Cafeteria

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**Abstract**

The purpose of this research is to develop a prototype of an automated cash register system for a cafeteria-type setting using digital-image processing techniques. The idea is to take an image of a cafeteria food tray containing food items, identify all the food items on the tray, and display the total food cost. The analysis method uses shape and size analysis to identify food items that are served on distinct types of dishes, and color analysis for those items that are served in similar dishes. This article explains the prototype of a developed system, and cites the experiment results for 10 types of meals served at Ritsumeikan Asia Pacific University Cafeteria to justify the validity of this approach. The article also discusses the feasibility of developing a fully automated system, which will incorporate biometric technology for identification of the customer for automatic debiting of the food's cost from the client's pre-registered account for a wider application of the system, e.g. in military settings.

**Keywords:** automated debit system, biometrics identification, color analysis, geometric analysis.

**Index terms:** machine vision, object recognition

## Introduction

In a highly industrialized country like Japan, where each aspect of life is being automated one after another, companies are working hard to provide a better service to

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the public at a much lower cost. Digital camera and computer technology is becoming very cheap and affordable, while their precision and performance are improving every day.

With this rapid development of digital camera and computer technology, image processing is now widely used in various industries. In the robotics industry, image processing is utilized to help robots recognize and interact with the surrounding environment (Samakming and Sirinonchat 2008). In the security industry, according to Vijaya Kumar (2002), image processing is used to analyze human faces, fingerprints, irises, etc. In the digital camera industry, according to Torige and Kono 2002), image processing is utilized to detect facial expressions, human gestures, postures and movements. Pishva et al. (2000a, 2001) has also shown the feasibility of using image-processing techniques to create a cash register system that recognizes handmade Japanese buns. Do (2009) and Do et al. (2010) have also shown the feasibility of using image-processing techniques to create a cash register system that recognizes cafeteria food items (Do 2009; Do 2010).

The aim of this research is a technical feasibility study of using a machine-vision system in a cafeteria-type setting. The envisioned application is a machine-vision-based cash register system that can automatically calculate and show the prices of different types of food on a tray in front of the system's camera, and use biometric technology for customer identification and for the automatic debiting of the food's cost from the customer's pre-registered account.

A fully automated "Machine-Vision-Based Cash Register System" for a cafeteria-type setting would consist of: (1) a digital camera which captures the image of a food tray, (2) a second digital camera that captures a biometric signature (e.g. the facial image) of the customer, and (3) digital-image processing software which can identify the food items on the tray, identify the customer through the biometric signature, and automatically debit the food's cost from a pre-registered customer account.

Figure 1 shows images of the traditional and the proposed system (see Appendix).

The proposed system can replace cashiers at a cafeteria; eliminate human errors; save on labor costs in a labor-expensive country like Japan; and provide a faster, smoother service, especially during busy periods such as lunchtime.

This article explains the implementation details of a developed prototype system, which uses area, shape and color analyses to determine the prices of cafeteria meals on a serving tray, and recommends its interface with standard biometrics technology to achieve a fully automated system.

## Measurement

Since pricing is to be based solely on the analysis of captured images, it is important to have accurate, consistent and reproducible conditions of measurement. This section gives some details of our procedure.

*Apparatus*
A simple web camera (2M Qcam Pro for Notebooks) was used to capture images of food servings on trays. A cubic shelf-type frame was used to maintain a fixed distance between the camera and the food trays. The camera was mounted to the center of the frame's top surface and the food trays were put on the frame's buttom surface, one tray at a time.

*Experiment set-up*
The camera's focal length was set to 3.7 mm, its zoom factor to minimum, its brightness, contrast, and color intensity to the factory default, and its auto white balance was turned off. To speed up the data acquisition and its associated processing time, the image size was set to 320 x 240 (QVGA), which was determined as optimal at this setting. A dark blue tray was used for effective background elimination.

*Image acquisition*
As an initial study, 5 different APU cafeteria food items were extensively measured and analyzed in the experiments. An image of these foods, together with an example of a typical Japanese meal in a university cafeteria is shown in Figure 2 (see Appendix). To fine-tune our analytical model, we took a number of images of these items (fish, 16 images; *karaage* [fried chicken], 15 images; *kani* [crab], 15 images; *nasu* [eggplant], 12 images; and rice, 13 images). Furthermore, images of 10 meals consisting of some combinations of these items were also captured.

## Analytical Approach

Using Matlab, our analytical approach was to identify which food items are served in different types of dishes, based on the shapes and sizes of the dishes; and to perform color analyses on those food items which are served in identical dishes. The intermediate data analysis included binarization, geometic analyses and color histogram analysis. As suggested by Pishva et al. (2002), the intermediate data from the color histogram analysis includes the transformation of RGB data to its HSI components.

*Overview of methodology*

The following method is used in both the modeling phase (eg, enrollment, calibration, training) and the application phase (eg, verification, prediction, usage). In the modeling phase, a statistical range for the shape, size and color information about a particular food item is extracted and, together with its cost, is stored as a template in a database. In the application phase, similar information is extracted from a newly acquired image of each food item on a customer's tray, and is compared with the registered templates in the database for price determination. An overview of the methodology is shown in Figure 3 (see Appendix).

*Binarization*

When Pishva et al. (2000c: 840-844) performed bread image binarization, he stated:

> [The] initial analysis stage was to binarize image data so as to extract its shape and size. Despite the fact that a uniform blue background was used for its easy elimination, none of the standard binarization algorithms perfectly worked with all the samples. Although there was no bread with explicit dark blue color or toppings, any arbitrary threshold setting eliminated parts of some food during background elimination. This is because [the lack of] uniform boundary shadows and [the] strong surface reflectance of some foods and their topping[s] greatly affected the process.

Furthermore, accrording to The Mathworks (2009), an associated Matlab function (true color image to binary image conversion) could not properly convert a multi-object true color image. Figure 4 shows a typical result of binarization, where one object (a key in this case, for clarity's sake) has completely disappeared in the binarization process (see Appendix). As such, the standard Matlab function could not be readily used in our specific case because the food trays contained more than one object.

In order to solve this problem, we introduced a new and effective approach. The following sequence of Matlab operations summarizes our successful binarization process:

*a. Convert true color image to gray image.*

*I = rgb2gray(OriginalImage)*

*b.Calculate the threshold value using the edge-detection function and the Sobel algorithm*

*[EdgeImage threshold] = edge(I, 'sobel')*

*c. Locate the edge of the object*

*[EdgeImage ] = edge(I, 'sobel')*

*d. Dilate the edge image*

*dilateImage = imdilate(EdgeImage, [se90 se0]);*

*e. Fill the inside of the object*

*fillImage = imfill(dilateImage, 'holes');*

*f. Remove noise*

*removenoiseImage = imopen(fillImage,se);*

Figure 5 shows the binarization result obtained according to the above sequence (see Appendix). As can be observed, all objects have been clearly extracted.

*Size analysis*

Size analysis extracts the area information of each object, i.e. the dishes on which food items are served, to determine if the object can be identified based solely on its extracted size information. In the APU cafeteria, some dishes are served on a uniquely-sized serving dish, and so can be identified based on size information alone. After binarization, the following Matlab functions were used to extract the size information:

*objData = regionprops( Label, ‘All’)*
*size = objData(i).Area*

Since we measured size information in pixel counts, the information varied slightly for the same dish, based on its location on the tray. This is because, despite the fact that we kept the distance between the camera and the serving tray constant, the absolute distance between camera lens and serving dish does vary slightly based on the dish’s location on the tray. Table 1 shows the fluctuation in serving dish sizes in pixel counts based on their relative locations on a tray.

After determining the above maximum and minimum size values of the serving dishes, we incorporated a 10% offset value (i.e. added 10% to maximum values and subtracted 10% from minimum values) to achieve a more reliable range. Table 2 shows the size information stored in our size database for the five serving dishes.

Note that although the fish and *nasu* dishes have different size information in Table 1, their sizes overlap in Table 2, due to the 10% reliability offset values that we incorporated. However, considering that the fish and *Nasu* items are served on dishes that have different shapes, we can use shape analysis for their identification. Similarly, as can be observed from Table 2, *karaage* and *kani* servings have similar dish area information, as they are served on the same type of dish (see Figure 2, Appendix). Hence, geometrics analysis will not be effective for their identification. According to

Pishva et al. (2000a, 2000c, we will use color analysis to distinguish them (Pishva et. al. 2000a; Pishva et al. 2000b).

*Shape analysis*

As suggested by Samieh (2007), shape analysis uses 3 parameters: area of object (dish), longation (ratio of the width to the length of the bounding box,) and MBR fill (ratio of the area of the object to the area of the bounding box). Because MBR Fill was always taken along the object's major axis, the sample's orientation did not affect this ratio.

In particular, the following method – a flowchart representation of which is shown in Figure 6 – was used to distinguish rectangular objects from circular ones (see Appendix). The actual code implementation in the Matlab environment is as follows:

```
If (abs(ObjData(i).BoundingBox(3)-ObjData(i).BoundingBox(4)) < 8) &&
    (ObjData(i).Extent >=0.9 )
 objshape = 0; %'square';
End
If (abs(ObjData(i).BoundingBox(3)-ObjData(i).BoundingBox(4)) < 8) &&
    (ObjData(i).Extent < 0.85 && ObjData(i).Extent > 0.78)
 objshape = 1; %'circle';
End
If (abs(ObjData(i).BoundingBox(3)-ObjData(i).BoundingBox(4)) > 8) &&
    (ObjData(i).Extent >= 0.9)
 objshape = 2;% 'rectangular';
End
```

*Color analysis*

When different foods are served on the same type of dish, size and shape analyses do not work effectively. Therefore, we used color analysis to distinguish between such foods. Figure 7 shows *Karaage* and *Kani*, which are served on the same type of dish (see Appendix).

Prior to data analysis, we transformed the image data from the RGB Color Space to the HSI Color Space. HSI closely resembles human perception of color, and its components are similar to an artist's concept of tint, shade and tone. In this system:

> hue is an attribute that describes a pure red, pure yellow, pure green etc. Saturation is another color attribute that describes the degree to which a pure color is diluted with white. The intensity of color image corresponds to its varying brightness levels. (Rembold et al. 1995)

The space in which these values are plotted can be shown by a circular cone, as indicated in Figure 8 (see Appendix).

In our color analysis approach, we used the saturation value as an indicator of whether a pixel in an image had sufficient color or not; that is, to distinguish a colored pixel from a monochromatic one. Experimentally, a threshold value of 64 (25% of full scale) was used for saturation. For colored pixels, we used the hue histogram to determine the specific color type; and for monochromatic pixels, we utilized the intensity histogram to distinguish black, grey and white pixels from each other.

The statistical values for distinguishing the color components of foods served in similar types of dishes were extracted and saved in the database during the modeling phase. A pictorial representation of this idea is shown in Figure 9 (see Appendix), where the left-hand image shows the cropped *Kani* item from Figure 7, while the right-hand image shows a binary image of its extracted red color. A cropped image of *Karaage* and its associated binary image of the extracted red color are shown in Figure 10 (see Appendix). As can be observed, using color analysis we can easily distinguish between these items.

As suggested by Kathi (2009), the actual Matlab function which detects a dish and its position on the tray, and then draws an ellipse around it, is shown below:

```
h = imellipse(gca,[ObjData(i).BoundingBox(1) ObjData(i).BoundingBox(2)
ObjData(i).BoundingBox(3) ObjData(i).BoundingBox(4) ])
```

Detection of specific color in an image was carried out according to the procedure described by Giannakopoulos (2008).

*Preliminary experiment results*

In this section we briefly explain the preliminary experiment results for when we used our prototype system for actual meal price estimation.

As a preliminary stage, we used 10 meals, which consisted of some combinations of the above mentioned items that were arranged randomly on serving trays. Our prototype system was able to successfully extract each food item on the tray, identify them by means of the size and shape of the dishes that they were served on, and employed color analysis when necessary. (To speed up the process, the analysis routine is designed in such a way that when a food item is identified by means of its dish size, shape and color analyses are not performed.) Table 3 shows the experiment result for the 10 served meals. All the prices were correctly estimated and displayed on a laptop computer used in the experiment.

## Conclusion

This article has explored a new application of image analysis. We have shown how the concept of image analysis can be used for the creation of a Machine-Vision-Based Cash Register System. We have demonstrated that area, shape and color analyses are effective methods of determining the prices of cafeteria meals on a serving tray. Data analysis is quite fast, since relatively coarse images were used in the process, and identification was carried out based on the shape and size of the dishes the items are served in, plus color analysis, rather than detailed analysis of the meals themselves. As such, the approach is especially useful for food items that do not have a distinct shape and size (e.g. rice, soup).

As our approach simultaneously analyzes all the food items on a tray, it is feasible for real-world application. A fully automated version can be achieved by coupling it with a standard biometric technology for customer identification and for automatic debiting of the food's cost from the customer's pre-registered account. Such an automated system can be particularly useful in cafeteria-type settings, such as those found in universities, military bases, and in large companies, which cater to large numbers of repeat customers.

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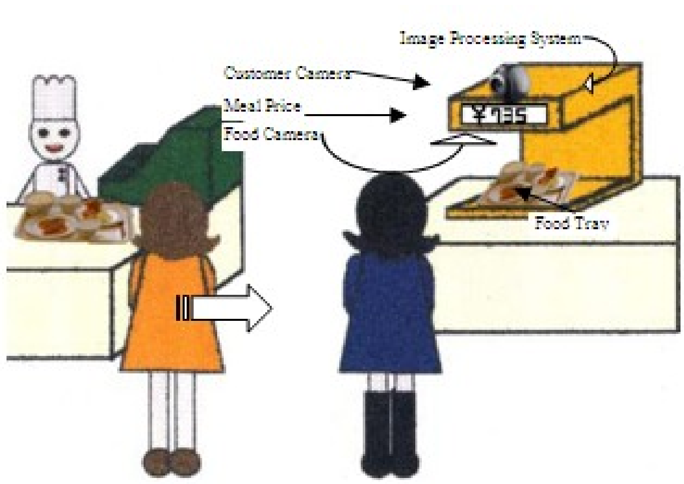
## Appendices

**Figure 1: Transition from a traditional system to a modern system**




(Left side: Traditional Cash Register System
Right side: Machine Vision Based Cash Register System).

**Figure 2: 5 types of food used during the expriment and an example of a served meal.**

**Figure 3: Overview of the analysis procedure.**

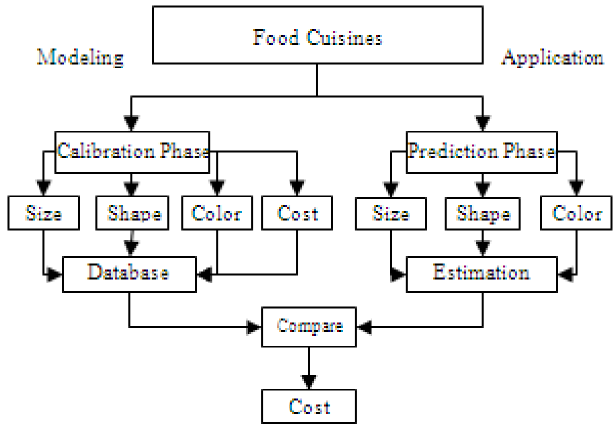



**Figure 4: Binarization result with standard Matlab fuction.**

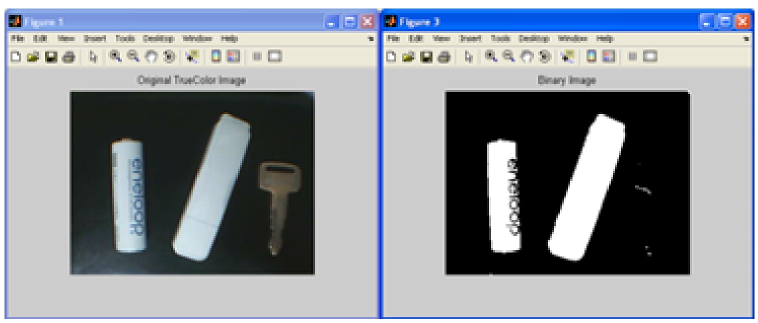



**Figure 5: Binarization result using enhanced approach.**

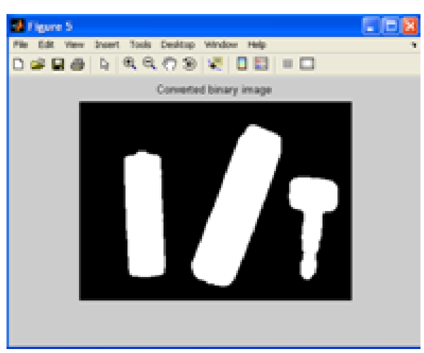


**Figure 6: Shape analysis algorithm.**

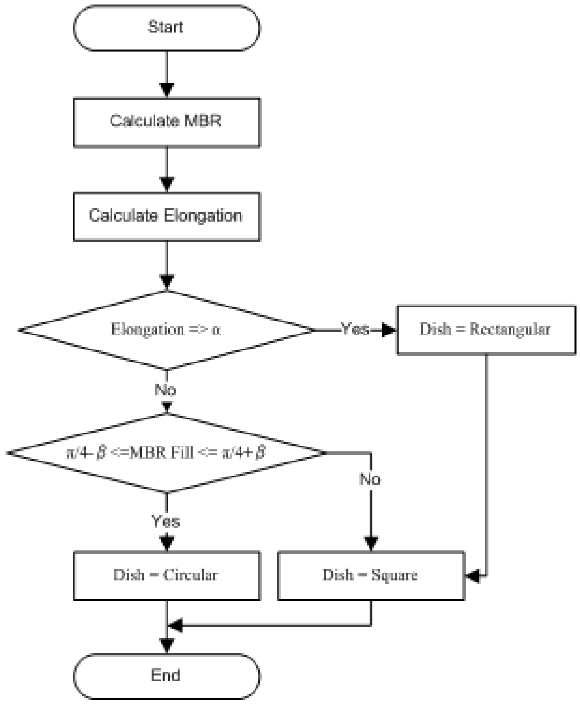



**Figure 7: Kani (left plate) and Karaage (right plate) servings.**

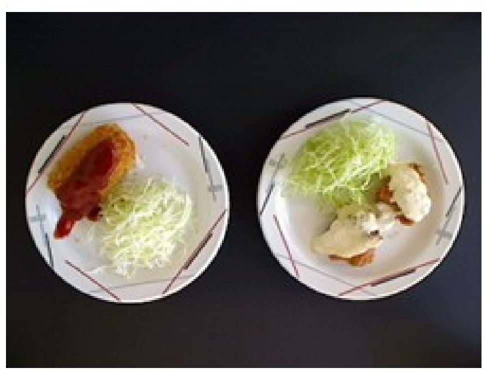


**Figure 8: Bi-conic representation of HSI space.**

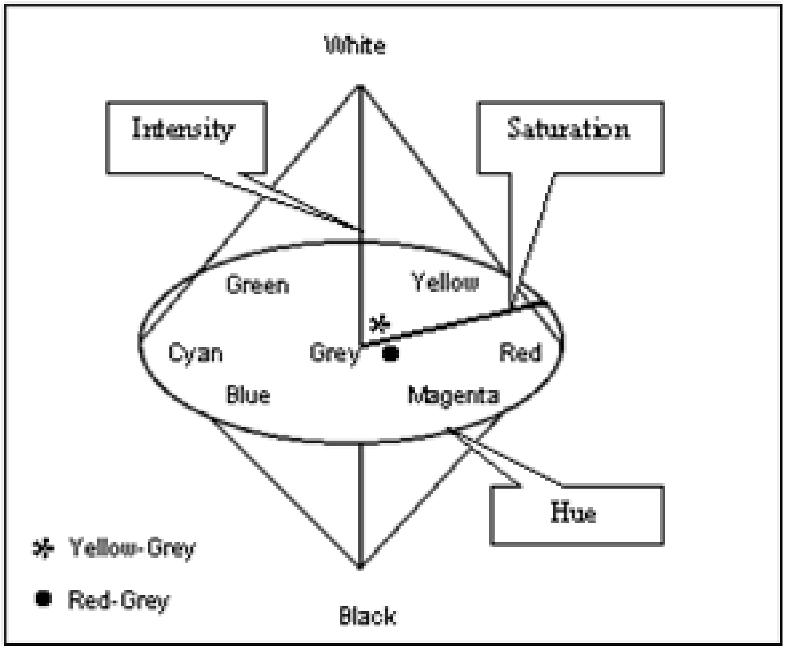



**Figure 9: Cropped Kani image of Fig. 7 and its detected red color.**

**Figure 10: Cropped Karaage image of Fig. 7 and its detected red color.**


**Table 1: Dish area fluctuations in pixel counts based on their locations on a tray (* means not measured).**

| Dish Location | Fish dish | Karaage dish | Kani dish | Nasu dish | Rice dish |
|---|---|---|---|---|---|
| 1 | 11381 | 15306 | 15315 | 13269 | 4911 |
| 2 | 11404 | 15323 | 15790 | 13069 | 4979 |
| 3 | 11403 | 15340 | 15763 | 12741 | 4963 |
| 4 | 11536 | 15834 | 15784 | 12527 | 5008 |
| 5 | 11824 | 15796 | 15899 | 12464 | 5072 |
| 6 | 11382 | 15329 | 16025 | 12336 | 4905 |
| 7 | 11055 | 15216 | 15676 | 12274 | 4733 |
| 8 | 10674 | 15712 | 15670 | 12352 | 4663 |
| 9 | 10959 | 15870 | 15426 | 12505 | 4549 |
| 10 | 10896 | 15454 | 15084 | 12537 | 4512 |
| 11 | 10771 | 15063 | 14852 | 12434 | 4614 |
| 12 | 10711 | 14949 | 14838 | 12340 | 4753 |
| 13 | 10747 | 15467 | 15403 | * | 4678 |
| 14 | 10721 | 15438 | 15658 | * | * |
| 15 | 11028 | 15845 | 15299 | * | * |
| 16 | 10980 | * | * | * | * |

**Table 2: Size database of 5 different dish types.**

| Dish | Min value | Max value |
|---|---|---|
| ***Fish*** | ***9376*** | ***13659*** |
| *Karaage* | *13454* | *17457* |
| *Kani* | *13354* | *17627* |
| ***Nasu*** | ***11046*** | ***14595*** |
| Rice | 4060 | 5579 |

**Table 3: Experimental result for 10 served meals.**

| Meal | Type | Cost (JPY) | Result |
|---|---|---|---|
| 1 | Karaage + Kani | 275 | Ok |
| 2 | Karaage + Kani + Rice + Fish | 505 | Ok |
| 3 | Rice + Kani | 200 | Ok |
| 4 | Fish + Kani | 305 | Ok |
| 5 | Nasu+Fish | 250 | Ok |
| 6 | Rice + Kani + Fish | 365 | Ok |
| 7 | Fish + Kani + Nasu | 385 | Ok |
| 8 | Nasu + Kani | 215 | Ok |
| 9 | Rice + Karaage + Nasu | 280 | Ok |
| 10 | Fish + Karaage + Nasu | 390 | Ok |