EXTRACTION OF CUSTOMER DEMOGRAPHIC CHARACTERISTICS IN SUPERMARKETS BASED ON IMAGE PROCESSING TECHNIQUES

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Abstract: Analysis of video data in a retail environment provides valuable information for business operators. Customer gender identification and age interval estimation are commonly used to better plan resources and marketing strategies. In this study, some demographic characteristics (gender and age interval) of hypothetical customers are extracted from video images. To extract gender information, geometric facial features are used. On the other hand, age intervals are estimated by measuring the size and proportions of the human face, and edge analysis as well. Besides, the trajectories of the customers are determined by image processing techniques. The preliminary experimental results show that promising clues are extracted to be used in the retail video analytics. In the future, we believe that these characteristics can be associated with heatmaps of customer walk-through patterns, which allows for optimal product placement and efficient floor setup.
Keywords: Retail Video Analytics, Customer Demographic Characteristics, Consumer Buying Behavior, Image Processing

Introduction

In recent years businesses are focused on satisfying the customer's needs and expectations in an efficient way than their competitors. Although the expectations of consumer markets are different from industrial markets, for both of the markets, the best way of meeting wants are based on identifying the consumers' needs and organizing the marketing activities according to them. At this point, the concept of consumer behavior becomes more important in the value creation process. Consumer behavior "is the study of the processes involved when individuals or groups select, purchase, use, or dispose of products, services, ideas, or experiences to satisfy needs and desires (Solomon, 2006: 7).''

In the literature, various studies are conducted to explore the impact of demographic factors on consumer behavior. Kumar (2014) expressed that demographic factors such as sex, age, marital status, ethnic, income, education, occupation and family size are the important factors which effect buying decisions. Hence, firms have to examine the demographic characteristics of the consumers carefully to plan their marketing activities efficiently. Therefore actually, customer demographic characteristics are important inputs for the businesses.

In the study, in order to understand the consumer behavior partly; image processing techniques are taken into consideration. By using image processing techniques, it is aimed to determine and understand the behavior of the consumers in a store. Briefly, there are two aims of the study. First one is to extract the customer demographic information in a hypothetical store, second is to determine the instore customer trajectories through image processing techniques. In this study, customer demographic characteristics are limited to gender and age. In this context, first consumer buying behavior is introduced. Next, extraction of customer demographic characteristics such as gender and age interval estimation is explained. Further, customer trajectory determination is discussed. Finally; results, discussion and conclusion are expressed.

Consumer Buying Behavior

From past to present, consumer buying behavior is the main research topic of marketers. Although many studies are focused on consumer buying behavior, still the reasons of the buying behavior of consumers cannot be discovered exactly. Moreover, for this reason, consumer's mind is like a black box. Hence, it is not so easy to answer the questions such as "when they buy?", "why they buy?", "what they buy?" etc. It is the truth that the success of the businesses is depending on understanding the expectations of the customers and planning all their

activities according to them. Product designs, pricing the goods and services, shelf designs etc. are among these activities. Herein, considering and studying the factors that affect consumers to behave in a certain manner are important (Khaniwale, 2015: 281).

According to Kotler and Armstrong (2012: 159), major factors that affect the buying behavior of consumers are classified as:

- Cultural factors
  Culture, subculture, social class
- Social factors
  Reference groups, family, roles and status
- Personal factors
  Age, life cycle stage, occupation, economic situation, lifestyle, personality and self-concept
- Psychological factors
  Motivation, perception, learning, beliefs and attitudes

Khaniwale (2015) classified the factors which influence consumer buying behavior as external and internal. External factors consist of cultural and social factors. On the other hand, internal factors are composed of personal and psychological factors.

Extraction of Customer Demographic Characteristics

In the context of video analysis, some demographic characteristics of hypothetical customers are extracted. These characteristics are determined as gender and age in the present study. Furthermore, the instore customer trajectories are detected through image processing functions.

Gender Estimation

Gender estimation is carried out using a portrait photo taken before entering the store. As a first step, the detection of face region is performed. To do that, Matlab's vision.CascadeObjectDetector function is used (https://www.mathworks.com/help/vision/ref/vision.cascadeobjectdetector-class.html, 07.08.2017). This function uses the Viola-Jones algorithm and detects people's faces, noses, eyes, mouth, or upper body (Viola and Jones, 2001). Then, the eye, nose and lip regions are cropped from the face. A sample detected face and the corresponding regions cropped from the face are shown in Figure 1.

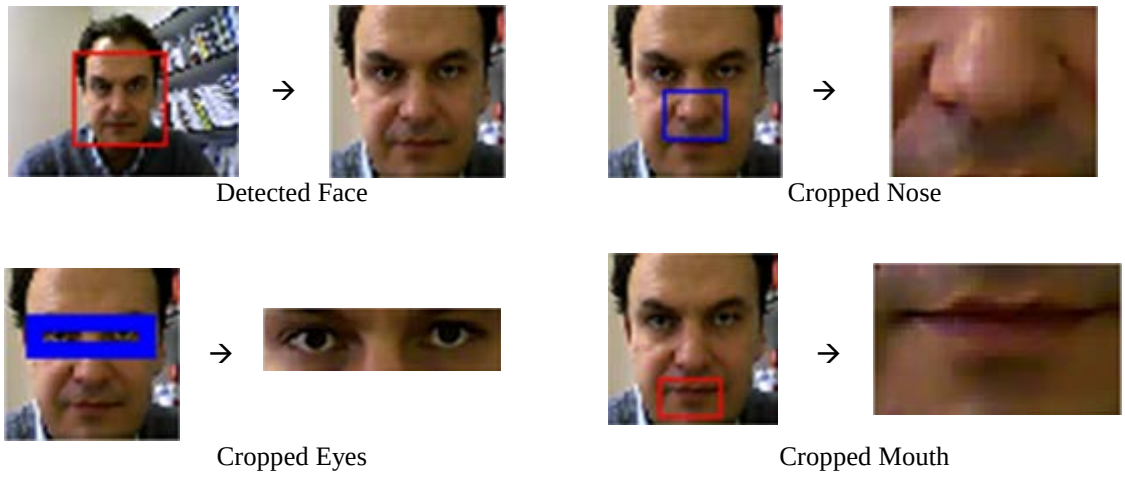

Figure 1. Results of face detection and face region cropping

After that four different ratios are computed using the geometric facial distances (Ramesha *et al.* 2010). The distances are illustrated in Figure 2, and the ratios are given in the following equations 1 to 4.

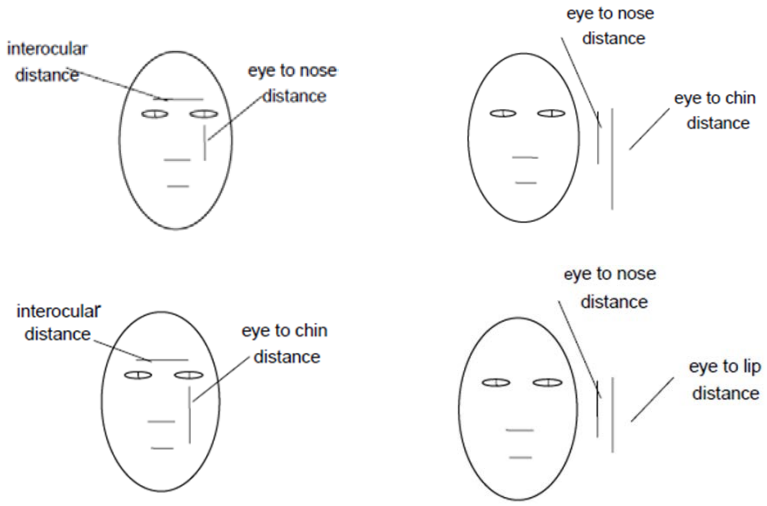

Figure 2. The distances used in gender detection (adapted from Ramesha *et al.* 2010)

$$Ratio1 = \frac{interocular\_distance}{eye\_to\_nose\_distance} \quad (1)$$

$$Ratio2 = \frac{eye\_to\_nose\_distance}{eye\_to\_chin\_distance} \quad (2)$$

$$Ratio3 = \frac{interocular\_distance}{eye\_to\_chin\_distance} \quad (3)$$

$$Ratio4 = \frac{eye\_to\_nose\_distance}{eye\_to\_lip\_distance} \quad (4)$$

The interocular distance is defined as the distance between the right and left eyes in the cropped face image. On the other hand, eye to nose, eye to chin and eye to lip distances are assumed as the distances between the line joining the eyes and nose tip (midpoint of cropped nose), lip (mid line of cropped mouth) and chin (bottom line of cropped mouth), respectively. After performing several experiments, optimum threshold values that differentiate male from female are determined for each ratio.

Age Interval Estimation

The age interval is estimated by the analysis of wrinkles. In the present study, three age intervals are considered which are (i) young, (ii) middle age and (iii) old. The regions labeled as "1" and "2" are used in the wrinkle map (Figure 3). These regions are automatically located for each face by generating buffer zones above and below the eye regions.

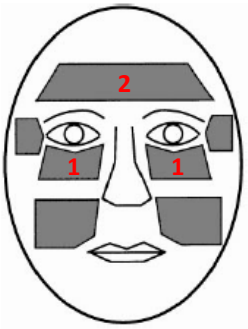

Figure 3. The regions of wrinkle map (adapted from Kwon and Lobo 1999)

To reveal the wrinkles, Canny edge detection operator is used (Canny, 1986). This operator uses a multi-stage algorithm to detect edges in images. It also provides low error rate, good localization and minimal detector

response per edge. The detected wrinkles (edges) on the cropped face image are shown in Figure 4. After obtaining all wrinkles, the edges fall within the predefined regions given in Figure 3 are counted. According to the number of lines counted, the age interval is determined. After performing numerous experiments, optimum separation values that differentiate three age intervals are determined.

Figure 4. Detected wrinkles on a sample image

Customer Trajectory Determination

In the final step, the instore trajectories of customers are determined by object segmentation techniques. In a video data taken from an oblique angle, the initial (empty) image frame is accepted as the background frame. The following frames are subtracted from the initial frame to reveal the moving objects. The moving objects are considered as customers in our hypothetical scenario. Sample moving objects segmented by background subtraction technique are illustrated in Figure 5.

Figure 5. The original image frames (left) and their segmented counterparts in binary form (right).

To determine the walking paths of the customers, segmented blobs are analyzed according to their Center of Mass (CoM) positions. To do that, for each image frame, the centroid points are computed for each isolated blob. These points found in each frame are marked on a still image cumulatively. Different colors are used for each customer to provide a better discrimination. In an example given in Figure 6, three different instore trajectories are obtained colored by yellow, green and blue.

Figure 6. Computed instore trajectories of three different customers.

Results and Discussion

The preliminary experimental results show that promising clues are extracted to be used in the retail video analytics. The tests are conducted on Chicago Face Database, which is developed at the University of Chicago (Ma *et al*., 2015). The database provides high quality, standardized face images of females and males between the ages 17-65. Of 50 female images chosen from the database, 32 were found to be correct (64% accuracy) in terms of gender and age interval. On the other hand, the accuracy of male images was computed to be 70% by predicting 35 images out of 50, correctly. The overall accuracy of the proposed approach is found to be 69%.

Although the proposed approach produces promising outcomes, some limitations are still apparent. First, instead of using real shopping videos with real customers, an indoor environment video with hypothetical customers is utilized due to difficulty in getting legal permissions. Second, the age interval is limited to three categories as young, middle age and old. More sophisticated prediction algorithms are needed to extend the age intervals.

Conclusion

Understanding the behavior of consumers is very important in the success of the businesses. On the other hand, it is the truth that understanding each of them is not so easy. In this situation, the best way is to make collaboration with other disciplines such as computer science and informatics.

As a matter of fact, consumer's behaviors are tried to be analyzed with image processing techniques. In this study, a preliminary video data analysis is performed in a retail environment, which provides valuable information for business operators. To do that, customer gender identification and age interval estimation are carried out, which are commonly used to better plan resources and marketing strategies. Besides, the instore customer trajectories are revealed by image processing algorithms. The overall accuracy of gender identification and age interval estimation is found to be 69%. The preliminary experimental results show that promising clues are extracted to be used in the retail video analytics.

As a future work, the demographic characteristics can be associated with heat maps of customer walk-through patterns, which allows for optimal product placement and efficient floor setup.

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