# Efficient Character Segmentation using Adaptive Binarization and Connected Components Analysis in Ubiquitous Computing Environments

Jongho Kim<sup>1</sup> and YongYun Cho<sup>2</sup>\*

<sup>1</sup>Dept. of Multimedia Engineering, Sunchon National University <sup>2</sup>\*Dept. of Information & Communication Engineering, Sunchon National University 255 Jungangno, Suncheon, Jeonnam 540-950, Korea {jhkim, yycho}@sunchon.ac.kr

### Abstract

In ubiquitous computing environments, many applications are devised to provide autonomous services. To make services autonomous, each service has to inevitably recognize the deployed devices or objects in ubiquitous computing environments. In order to provide an autonomous service based on vision system, we address an efficient character segmentation algorithm by means of introducing the locally adaptive binarization and the object labeling by Connected Components Analysis (CCA). The proposed binarization technique carries out the grayscale-to-binary image conversion with block-based processing to reflect the local variation of images. The object labeling by CCA algorithm is applied to the binarized image with the morphological operation in order to improve the object connectivity. Experimental results show that the proposed algorithm can segment each object reasonably even with atypical or erratic form. Therefore, the proposed algorithm can be useful for development of various applications in ubiquitous computing environments.

*Keywords:* Ubiquitous Computing; Character Segmentation; Binarization; Connected Components Analysis; Object Labeling

## **1. Introduction**

Recently, many research interests for ubiquitous computing have been widely expanded to various industrial areas such as u-harbor port, u-city, u-health, u-office, and so on. Commonly, a work in ubiquitous computing environment aims to autonomous and intelligent without human's intervention. Especially, most works in the wide open area such an airport, a harbor port, and a manufacturing factory is harder than other work environments. Thus the work automation is urgently needed in these environments. Until now, many researchers have adopted ubiquitous technologies in their research projects for smart works or intelligent services. Currently, smart works and intelligent services in ubiquitous environments are based on sensor technologies and network technologies [1-2]. Moreover, ubiquitous environments have erratic characteristics and consistent work conditions. Therefore, an efficient algorithm to exactly recognize various service objects through sensors is very important to offer appropriate smart services in ubiquitous environments.

Character segmentation technique is also adopted in various fields for many purposes. One of the most remarkable fields is the recognition of information and its application to the automated logistics systems. Many studies to obtain the product information automatically have been carried out in recent years such as the barcode and the Radio Frequency

<sup>\*</sup>Corresponding author: YongYun Cho

Identification (RFID) technology [2]. However, it is difficult to place the reader device near the barcode accurately. Moreover, the barcode is inclined to be damaged when the products are transported. The RFID tag can be also damaged easily when the products are moved here and there or piled up. Specifically, the RFID tag located at the side face of the steel plates is difficult to be recognized due to the shade area caused by accumulation of steel plates of different sizes. The character recognition technology is considered in order to overcome these drawbacks of conventional methods in our work.

This paper proposes a character segmentation algorithm applied to steel plate images in order to extract product information located at the side of each steel plate. The proposed algorithm consists of an adaptive binarization algorithm of a grayscale image and an object labeling algorithm by the Connected Components Analysis (CCA) for the binarized image. The steel plate images can contain noises and external effects due to lighting, weather, time, place, and so on, since they are generally obtained outside a room. Thus the binarization algorithm should be robust to these poor conditions for effective results hereafter. In our work, each character is printed to the side of each steel plate in a horizontal line-based fashion. This reduces the vertical connectivity in each character, and thus it can disturb the appropriate segmentation of characters by means of CCA. To overcome this problem, we apply a morphological operation prior to the CCA in the vertical direction, which improves the vertical connectivity of each character. Since the piled steel plates have various sizes and thickness, the sizes and locations of the characters of each steel plate can be different from each other. To extract characters more effectively in this environment, we apply a directional projection to the binary image obtained by using the CCA-based labeling technique, which includes the horizontal projection to segment each steel plate and the vertical projection to segment each character from the segmented steel plate.

The rest of the paper is organized as follows. Section 2 describes the related works in terms of character segmentation and recognition methods including the license plate recognition methods in ubiquitous computing environments. In Section 3 we present the proposed character segmentation algorithm in detail, which includes a locally adaptive binarization and the object labeling by CCA. Experimental results from each segmentation step and conclusions are provided in Sections 4 and 5, respectively.

## 2. Related Works

Many impressive researches have been accomplished in the field of ubiquitous computing environments based on the character segmentation technique [3-6]. Choubey and Sinha presented new methodology for the image segmentation and character recognition from the standard Indian vehicle plates in [6]. The method can classify similarities among the alphabetic characters efficiently, and it can be adopted in various fields, especially smart applications in ubiquitous computing environments such as a smart car, a smart building, and a smart office.

In order to segment each character from various types of images including document images, the conventional researches have introduced many binarization algorithms, which isolate the character areas from other features of the image effectively. For the binarization, a threshold value should be selected appropriately to minimize the misclassification error illustrated in Figure 1, where the left figure represents intensity histogram showing foreground and background peaks; the right figure represents the tails of the foreground and background distributions are extended to show the intensity overlap of the two distributions [7]. It is evident that this overlap makes it impossible to correctly classify all pixels by means of a single threshold. The minimum-error method of threshold selection minimizes the total misclassification error.



### Figure 1. Illustration of Misclassification Error in Thresholding for Binarization

Figure 2 shows the general structure of the binarization algorithms for the document images based on the thresholding technique. O'Gorman in [7] proposed a global thresholding approach computed from a measure of local connectivity information to minimize the misclassification error. That is, the thresholds are found at the intensity levels aiming to preserve the connectivity of regions.



### Figure 2. General Structure of Binarization Algorithms for Document Images

Liu, et al., proposed a method for document image binarization focused on noisy and complex background problems in [8]. They used grayscale histogram and run-length histogram analysis in a method called object attribute thresholding. It identifies a set of global thresholds using global techniques which is used for final threshold selection utilizing local features. Yang, et al.'s thresholding algorithm is based on a statistical measurement, called largest static state difference [9]. The method aims to track changes in the statistical signal pattern, dividing the level changes to static or transient according to a gray-level variation. The threshold value is computed according to static and transient properties separately at each pixel. Stroke connectivity preservation issues in textual images were examined by Chang et al. in [10]. They proposed an algorithm that used two different components: the background noise elimination using gray-level histogram equalization and enhancement of gray-levels of characters in the neighborhood using an edge image composition technique. The binary partitioning is made according to smoothed and equalized histogram information calculated in five different steps. Sauvola, et al., in [11] proposed an algorithm for the adaptive document image binarization based on the structure of Figure 2. It first performs a rapid classification of the local contents of a page into background, pictures, and text. Two different approaches are then applied to define a threshold for each pixel: a soft decision method (SDM) for

background and pictures, and a specialized text binarization method (TBM) for textual and linedrawing areas. The SDM includes noise filtering and signal tracking capabilities, while the TBM is used to separate text components from background in bad conditions, caused by uneven illumination or noise.

Moreover, a similar topic to our work can be found in the license plate recognition algorithms, where the input image usually contains one car (or more cars), and the location and color information of the license plate can be used to detect the plate and segment each character [12-17]. Color- or grayscale-based processing methods were proposed in the literature for determination of the license plate location [14, 17]. Crucial to the success of the color (or gray-level)-based method is the color (gray-level) segmentation stage. On the other hand, solutions currently available do not provide a high degree of accuracy in a natural scene as color is not stable when the lighting conditions change. Since these methods are generally color-based, they fail at detecting various license plates with varying colors. Although color processing shows better performance, it still has difficulties in recognizing a car image if the image has many similar parts of color values to a plate region. An enhanced color texture-based method for detecting license plates in images was presented in [5]. The system analyzes the color and textural properties of license plates in images using a support vector machine (SVM) and locates their bounding boxes by applying a continuous adaptive mean shift algorithm.

The character recognition of steel plates is, however, different from the license plate recognition due to multiple tags and irregular arrangement of each steel plate. In addition, we apply the proposed algorithm to the grayscale images, since the colors in steel plate images do not contain useful information as shown in Figure 3, which represents an example of the steel plate image with tags representing product information. Each tag is attached to side face of each steel plate and the product information is recorded in black in the white background area.

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Figure 3. An Example of the Steel Plate Image with Tags to be Detected

## **3. Proposed Algorithm**

The proposed character segmentation algorithm is consists of several techniques: locally adaptive binarization, morphological processing to improve connectivity of the objects, CCA-

based object labeling, and directional projection. The overall structure of the proposed algorithm for the character segmentation is shown in Figure 4.



Figure 4. Overall Structure of the Proposed Character Segmentation Algorithm

#### **3.1. Adaptive Binarization**

The grayscale images including product information can be obtained under various conditions such as illumination, weather, time (day or night), and so on. To reduce the effects of the conditions, we divide the image into blocks and apply the binarization algorithm to each block. For each block, we utilize the Otsu's binarization in which the threshold is automatically selected according to the image characteristics [19]. The Otsu's method obtains the threshold by using

$$\eta(th) = \max_{1 \le th < L} \left[ \frac{\sigma_B^2(th)}{\sigma_T^2} \right], \qquad (1)$$

where  $\sigma_B^2(th)$  and  $\sigma_T^2$  represent the between-class variance and total variance, respectively, and *L* is a maximum value of a gray-level. In (1), the between-class variance is defined as

$$\sigma_B^2(th) = \frac{\left[\mu_T \omega(th) - \mu(th)\right]^2}{\omega(th) \left[1 - \omega(th)\right]}, \qquad (2)$$

where  $\omega(th)$  and  $\mu(th)$  are the sum of probability and mean value under the threshold, respectively, and  $\mu_r$  is a mean of the image.

The Otsu's method is motivated by a conjecture that well-thresholded classes would be separated in gray levels, and conversely, a threshold giving the best separation of classes in gray levels would be the best threshold. The Otsu's method adopted in our approach is characterized by its nonparametric and unsupervised nature of threshold selection and has the following desirable advantages:

- The procedure is very simple; only the zeroth and the first order cumulative moments of the gray-level histogram are utilized.
- A straightforward extension to multi-thresholding problems is feasible by virtue of the criterion on which the method is based.
- An optimal threshold (or set of thresholds) is selected automatically and stably, not based on the differentiation (*i.e.*, a local property such as valley), but on the integration (*i.e.*, a global property) of the histogram.

- Further important aspects can be also analyzed (*e.g.*, estimation of class mean levels, evaluation of class separability, *etc.*).
- The method is quite general; it covers a wide scope of unsupervised decision procedure.

Taking into account these advantages of the Otsu's method, which provide a global threshold, we apply it adaptively by means of the block-based fashion to reduce the external effects.

## **3.2. Character Labeling by CCA**

The objects including characters are labeled by using the CCA (Connected Components Analysis) with 8-connectivity [21]. We also apply the morphological operation before the labeling in order to improve the connectivity of each object [20]. Among various morphological operations, we apply the closing operation with the structuring element of  $1\times3$  in order to improve the vertical connectivity of each character. In our work, the tags are printed by spraying black paints in horizontal line-by-line, thus each character in the tags shows weak connectivity in vertical direction.



(a)



(b)

Figure 5. Effects of the Morphological Closing Operation on the Vertical Connectivity of Each Character (indicated by red circles): (a) without Morphological Operation, (b) with Morphological Operation

The closing operation of a image A by structuring element B, denoted  $A \bullet B$ , is defined as

$$A \bullet B = (A \oplus B) \ominus B \tag{3}$$

which, in words, says that the closing of *A* and *B* is simply the dilation of *A* by *B*, followed by the erosion of the result by *B*. In (3), the symbols  $\oplus$  and  $\ominus$  represent the dilation and erosion operations, respectively. Figure 5 shows the effect of the closing operation on the improvement of connectivity. After application of the morphological operation to the binary image, we carry out the labeling by using CCA with 8-connectivity.

The labeled objects include noises and undesired objects as well as the characters to be segmented. In order to select the characters among the labeled objects, we define two criteria such as a width-height ratio and angle. Figure 6 shows a result of the character selection criteria, that is, the hyphen object in Figure 6(a) is removed in (b). The proposed algorithm uses the width-height ratio of each character with range between 0.3 and 0.9, and the angle criteria with 75 degrees.



(b)

Figure 6. Results of the Character Selection Criteria Applied to the Labeled Objects; (a) Labeled Objects Indicated by Rectangular Bounding Boxes, (b) Selected Characters

### **3.3. Directional Projection**

Finally, the horizontal projection is performed in order to localize the character sequence (*i.e.*, product information tag) of the corresponding steel plate. Each character contained in the localized character sequence can be segmented by using the labeling information, which is top-left and right-bottom coordinates for a rectangular bounding box of an object. The directional projections are performed with the line-based fashion, which replaces each line of the image with a standard deviation value. Figure 7 illustrates a result of the horizontal projection for the case of two steel plates.



(a)



(b)

Figure 7. Result of the Horizontal Projection by using the Line-based Standard Deviation; (a) Selected Characters, (b) Horizontal Projection, which can Separate each Steel Plate

# 4. Experimental Results

To evaluate the proposed algorithm, we have applied each step described in Figure 4 to a grayscale image of steel plates shown in Figure 8. The image contains two steel plates and character sequences, that is, product information tags in each plate. We can see the tags are placed at the side face of steel plates, and consist of Arabic numbers, hyphens, and some capital English letters.



Figure 8. A Grayscale Image of Steel Plates (824×642)

Figure 9 shows the result obtained by the proposed binarization algorithm. The binary image includes some noises and uninterested objects such as lines and dots as well as characters. Moreover, some characters are disconnected vertically, since the product information is printed by line-based fashion. To improve the vertical connectivity, we apply the morphological closing operation to the binary image. The results of the morphological closing operation can be seen in Figure 5.

The results of the labeling by CCA followed by the morphological closing operation and the character selection criteria are shown in Figure 6. As a final result, the segmented characters from the image of Figure 7(a) are shown in Figure 10. We can see from Figure 10 that the proposed segmentation algorithm separates each steel plate and extracts each character in the corresponding plate



Figure 9. A Binary Image Obtained by the Proposed Adaptive Binarization Algorithm



Figure 10. Segmented Characters from the Image of Figure 7(a)

# **5.** Conclusions

This paper proposes a new character segmentation algorithm based on the locally adaptive binarization and the object labeling by CCA. The proposed binarization technique carries out the grayscale-to-binary image conversion with block-based processing to reflect the local variation of images. The object labeling by CCA is applied to the binarized image with the morphological operation to improve the connectivity of each object and remove noises. The proposed algorithm can be widely used to develop various smart and autonomous service applications in ubiquitous computing environments.

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# Authors



**Jongho Kim** received B.S., M.S., and Ph.D. degrees in electronic communications engineering from Hanyang University, Seoul, Korea, in 1998, 2000, and 2008, respectively. From 2008 to 2009, he worked at Samsung Electronics Company, Korea. He is a Professor at Dept. of Multimedia Engineering, Sunchon National University. His research interests include image/video coding and multimedia signal processing.



**YongYun Cho** received his BE in Computer Science from Inchoen University, Korea, in 1995, and received MS and PhD in Computer Engineering from Soongsil University, Korea, in 1998 and 2006, respectively. Currently, he is a Professor at Dept. of Information and Communication Engineering, Sunchon National University. His research interests include context-aware workflow, smart computing and robot.