Indonesian Journal of Electrical Engineering and Computer Science
Vol. 14, No. 2, May 2019, pp. 887~894
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v14.i2.pp887-894

Vacant parking space identification using probabilistic neural network

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Article Info

Article history:

Received Sep 29, 2018
Revised Nov 26, 2018
Accepted Dec 9, 2018

Keywords:

Identification
Image processing
Invariant moment
Parking location
Probabilistic neural network

ABSTRACT

The need for public parking space is increasing nowadays due to the high number of cars available. Users of car parking services, in general, are still looking for vacant parking locations to park their vehicle manually. With the current technological developments, especially in image processing field, it is expected to solve the parking space problem. Therefore, this research implements image processing to determine the location of vacant parking space or occupied ones that run in real-time. In this study, the proposed method is divided into five stages. The first stage is image acquisition to capture the image of parking location. Then it continues to pre-processing stage which consists of the process of saturation, grayscale and thresholding. The third stage is image segmentation to cut the image into five parts. The next stage is feature extraction using invariant moment, and the last stage would be identification process to determine the location of vacant parking spaces or occupied ones. The results of this research using 100 test images generates an accuracy, recall, and precision of 94%.

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1. INTRODUCTION

The rapid increase in the number of vehicles in large cities has an impact on the need for public parking spaces in such places as hospitals, offices, shopping centers, universities, recreation areas and others. The limited area of parking lots and the number of cars in the parking lot may cause trouble to car drivers in looking for a vacant parking spot, making the drivers have to circle the parking area to find one. Efficient arrangement of the parking area is required without overriding the convenience aspects of the users so that the determination of the parking spot along with its travel time can be more efficient.

As the technology develops rapidly, the control system is mandatory to minimize errors. The development of information technology can be seen through digital image processing that can be expanded to help humans in their daily activities. Digital image processing is one of the methods to solve the problem of image processing. The image will be processed in such a way that the image can be easier to process and be converted into information.

In general, the location of private-owned parking is equipped with a low-quality Closed Circuit Television (CCTV) camera which is useful to monitor the parking location state. Whereas this study requires a high pixel image quality to get the best result. Due to the authors' financial constraint, Digital Single Lens Reflex camera (DSLR) was used as an alternative. In terms of quality, the image produced by DSLR cameras has a high pixel quality, however DSLR camera is less efficient to be placed in the parking lot. In addition, the authors also applied data communication techniques in real-time so that the vacant parking locations can be determined in a short time.

Al-Kharusi and Al-Bahadly researched in 2014 about a system combining multiple image processes to produce easily detectable imagery of any location that is vacant and occupied by assigning a red color meaning that the spots are occupied and blue meaning vacant spots. The drawback of this study is the weather can affect the result. However, it can be enhanced by a high-quality image filtering so that the camera can detect vacant spots either in good or bad weather conditions [1].

Q Wu and Y Zhang once set up a system for Parking Lots Space detection in 2006. Using the SVM and Gaussian Ground Color Model systems, this study has an accuracy rate of 83.57%. The downside of this system is that it takes time to split into multiple frames, and the system does not work in real-time [2].

In 2012 J Zhu, H Cao and H Liu developed a Parking Space Detection. They created a system that can detect the vacant parking location from an image and a sensor. The authors proposed to apply other algorithms that can combine information from sensors and images so that parking can be more easily identified for further research [3].

Nicholas True in 2007 once created a system to detect a vacant location in static images. This system produced a fairly high level of accuracy using Support Vector Machine, and K-Nearest Neighbor with Support Vector Machine Algorithm generated a higher level of accuracy. By combining the color histogram and vehicle feature detection, the system produced a great result [4].

H Bhaskar, N Werghi and S Al-Mansoori in 2011, conducted research using CCTV to determine vacant locations, CCTV was placed on top of the building to see all parking locations. They used the Scale Invariant Feature Transform (SIFT) method to produce fairly accurate result [5].

Parking location is one of the essential aspects, especially in metropolitan cities that require extensive parking. Users of parking services, in general, still need to search for a vacant parking location manually by circling the parking location. With the rapid technological developments, it is expected to be utilized in helping to solve the parking space problem without putting aside the comfort aspects of users. Thus, it is necessary to build an automatic and intelligent parking information system through digital image processing to ease the parking service users to find a parking spot at a short time.

2. RESEARCH METHOD

The method proposed by the authors to determine the vacant parking location consists of several processes. The process will be performed as follows: The image taken from DSLR camera will be processed then enter the image pre-processing process. In this process, the image will go through the process of saturation, grayscale and thresholding which will produce black and white images with sharper contrast to simplify the system to perform the next process. Then there will be a cropping process where each car park location will be cut per the desired amount. The following process is the application of the Probabilistic Neural Network (PNN) method to identify which locations are vacant or occupied with cars and the final result will be more accurate with the application of this algorithm. The general architecture of this study is shown in Figure 1.

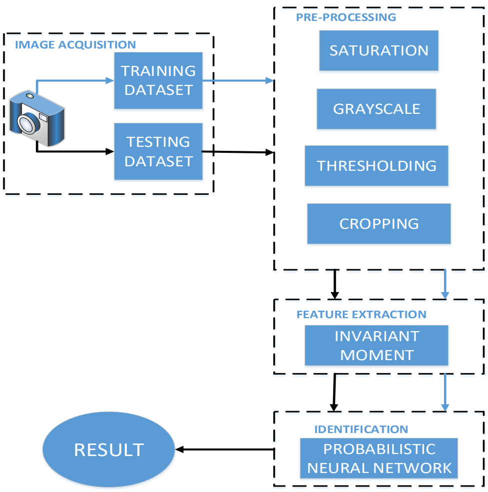


Figure 1. General architecture

2.1. Image Capturing

The parking location image used for the input is an image that can accommodate five cars. The input for this stage is an image taken from Digital Single Lens Reflex DSLR camera, and the system will capture the image every 30 seconds to be processed to the next stage.

2.2. Data Training

The training data in this research is divided into 2, i.e., a fully-occupied parking area training data and training data of vacant parking spots. The data will be stored in the database to simplify the system. As for the number of the fully-occupied parking slots data training is 40 images and each image is divided into five training data, making a total number of 200 training data. While training data for vacant parking consists of 20 images making a total of 100 training data.

2.3. Data Testing

Data testing is the data used to test the system. With the data testing, the system can identify the occupied parking spot by comparing the data with training data. The data used is taken from a DSLR camera with a particular angle that will produce an image to be processed to the next stage. Data testing in this study consists of 20 images with a total of 100 data testing.

2.4. Pre-processing

Pre-processing is one of the early stages of this study which consists of saturation, grayscaling and thresholding processes. This process aims for the data to be easily interpreted for analysis, so the result becomes more optimal. Samples of pre-processing convert the RGB image (Red, Green, Blue), binary image, image cropping, image resizing, edge detection or edge enhancement and thinning [6].

2.4.1 Saturation

In this process, the image will be set to be brighter and sharpened to get an optimal result. Afterward, the color of the image will be dominated by orange, and the image becomes more visible.

2.4.2 Grayscale

Grayscale process is the process of converting the red, green, blue (RGB) colors to the gray level. This process is to facilitate the system to know the value of the image and to simplify to the next process of thresholding [7].

2.4.3 Thresholding

A typical extraction technique is the thresholding method. The method is simple, and its similar criteria are based on the range of gray values that belong to the corresponding feature, which is used as a threshold to separate it from the image background. Thresholding is usually applied to monochrome maps where the map elements are very different from the general background or on the gray image. In general, thresholding process to grayscale image aims to produce a binary image [8]. Then the color of the image will be black and white with sharper image quality.

2.5. Image Segmentation

Image segmentation is a process to cut the image into several sections per number of parking locations available to facilitate the system to detect vacant parking locations. The image will be processed by every existing piece. In this study, there are five pieces of imagery that indicate the parking location can accommodate five cars on each piece. Each parking slot is symbolized as A1, A2, A3, A4, and A5 to make it easier for the system to identify the existing parking slot.

2.6. Feature Extraction

The feature extraction of image objects is based on two-pixel characteristics which are the similarity and the difference in pixel values. In other words, how the discontinuation of the gray pixel values are treated and when the intensity values changes based on certain criteria are appropriate or not to indicate a boundary between different images features [9]. In this study, the authors used invariant moment method which is often used as a feature in image processing, pattern recognition, and classification. The moment can provide characteristics of an object that represents its shape uniquely. The results of this method are seven values on each image object. These values are independent of translation, rotation, and scaling. Traditionally, the invariant moment is calculated based on information provided by boundary shapes and interior regions [10] which can be calculated using equation below.

$$m_{pq} = \sum_{x=0}^{h-1}\sum_{y=0}^{w-1} x^p y^p f(x,y)$$

The result of this method is in the form of 7 values to be used in the next process. The sample result of this method is shown in Table 1.

Table 1. Sample Result of Invariant Moment

Φ	A1
Φ_1	5.002232689471448
Φ_2	11.042582927921714
Φ_3	18.13266886354278
Φ_4	18.015612319433743
Φ_5	36.72727032454642
Φ_6	24.422749453801575
Φ_7	35.854622954395154

2.5. Identification using PNN Algorithm

The Probabilistic Neural Network (PNN) is an artificial neural network that uses classical probability theories such as Bayes classification and Parzen density approximation. A process implementing PNN may require a shorter time compared to Backpropagation neural network. The accuracy of the PNN classification is mostly determined by the value of σ and the training pattern. If the value of σ applied to PNN is correct, then the classification accuracy will be close to or has reached 100%. If the value of σ applied is not accurate, then the accuracy of the PNN classification will decrease [11].

In this research, 20 images are used as the input with a total of 100 test data. The image was taken from the parking lot of North Sumatra University Hospital. After the values of the invariant moment were obtained, the next process is using Probabilistic Neural Network algorithm to get a more accurate result which can be calculated by using equation as follow:

$$fA(X) = \frac{11}{(2\pi)^{p/2}\sigma^{pm}} \sum_{i=1}^{m} \exp[-(x - \frac{(x_{Ai})^t (x - x_{Ai})}{2\sigma^2}]$$

Where i is the number of patterns, m equals the number of training patterns, X_{Ai} represents training pattern of i from θA category, σ is the mean parameter and p is the dimensional space size.

Note that fA (X) is a simple equation of small multivariate Gaussian distributions that centered on each training sample. However, the numbers are not limited to being Gaussian. This may occur due to the estimation of the density probability function. There is a real similarity between parallel analog networks that classify multiple patterns using density probabilities (PDF) and feed-forward neural networks implemented with other training algorithms [12].

3. RESULTS AND ANALYSIS

This chapter presents the result of the conducted research to identify the vacant parking locations using real-time dataset taken from North Sumatra University Hospital using DSLR camera.

3.1. Capturing Image

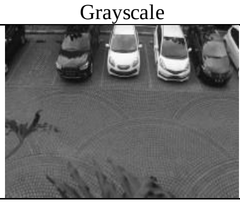
The result of capturing image process is the images taken from the parking location of North Sumatra University Hospital using DSLR camera every 30 seconds in real-time with jpg format. The sample of this stage is shown in Figure 2.

Figure 2. Result of capturing image

3.2. Pre-processing

The result of this process is in the form of images that have been through the process of saturation, grayscale and thresholding. The result can be seen in Table 2.

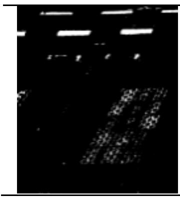
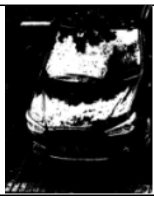
Table 2. Pre-processing Result

Saturation	Grayscale	Thresholding
		

3.3. Image Segmentation

Image segmentation is a process of cutting the image into five parts per the number of parking slots captured by the camera. Each slot is divided into A1, A2, A3, A4, and A5 to make it easier for the system and driver to identify each slot. The result of this process can be seen in Table 3.

Table 3. Image Segmentation Result

A1	A2	A3	A4	A5
				

In Table 3, the displayed image is the image that has gone through the thresholding process with a sharp contrast to identify the value of each pixel in the image. The size of each parking slot can be seen in Table 4.

Table 4. Image Segmentation Result

Parking Area	Size
A1	1000 x 1200 pixel
A2	950 x 1200 pixel
A3	1000 x 1200 pixel
A4	950 x 1200 pixel
A5	1184 x 1200 pixel

3.4. Feature Extraction

The next process is feature extraction. In this stage, every cropped image will be processed to generate the seven values of the invariant moment. Every image captured by the camera produces five cropped images. Therefore one image captured by DSLR camera will produce 35 invariant value moment to be used in the next process of Probabilistic Neural Network (PNN) implementation. Feature extraction result is shown in Table 5.

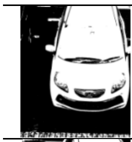
Table 5. Invariant Moment Result

Φ	A1	A2	A3	A4	A5
Φ1	4.098-	6.278-	7.042-	6.739-	6.733-
Φ2	9.943-	14.03-	16.08-	15.40-	14.71-
Φ3	13.41-	20.89-	2.898-	22.96-	22.70-
Φ4	13.56-	21.55-	23.54-	24.08-	22.49-
Φ5	28.10-	46.06-	48.07-	51.01-	45.52-
Φ6	18.98-	29.90-	31.75-	32.85-	30.22-
Φ7	27.15-	43.46-	48.18-	48.50-	47.49-

3.5. Identification using PNN Algorithm

The process continues to identification process using PNN where the value of invariant moment obtained in the previous research served as the initial value in PNN implementation. The invariant moment values of data testing will be compared to the value of data training to facilitate the system to identify the vacant and occupied parking spaces. This process will generate the value of fA(X) which means a simple sum of small multivariate Gaussian distributions that centered on each training sample. The result of PNN calculation is shown in Table 6.

Table 6. PNN Result

Cropping	fA1(X)	fA2(X)	Result
	0.9263316-	1.2343760-	True
	4.9766164-	0.7629464-	True
	5.2080348-	0.4901934-	True
	6.1670307-	0.3034747-	True
	4.6978095-	0.3361874-	True

Where fA1(X) represents PNN calculation result of occupied space image, while fA2(X) is the PNN calculation result of vacant spot image.

Based on the result, the values of fA1(X) and f2(X) will be compared. If fA1(X) value is greater than fA2(X) then it is filled, however, if fA2(X) is greater, the image shows a vacant parking spot.

3.6. Accuracy

In this study, the Gaussian value used is 0.9 because it is the most accurate value based on the test results. The accuracy rate of the system is obtained by calculating the amount of correctly identified test data divided by the total of test data multiplied by 100%. From the calculation, the accuracy rate of this research is 94%.

$$Acuracy\ Persentage = \frac{number\ of\ correctly\ identified\ data}{total\ of\ test\ data} x\ 100\%$$

$$= \frac{94}{100} x\ 100\% = 94\%$$

3.7. Precision and Recall Analysis

In pattern recognition and information retrieval, precision and recall are two calculations that are widely used to measure the work of a system. Precision is the level of accuracy between the information requested by the user and the answers given by the system. A recall is the system success rate in rediscovering information. Precision and recall in this research were used to measure the performance of Probabilistic Neural Network (PNN) algorithm to determine the vacant or occupied parking locations. 100 data of the parking location images taken from University of North Sumatra hospital were used to test the system. Result of analysis as shows in Table 7.

Table 7. Result of Analysis

Relevant (a)	irrelevant (b)	Total (a+b)	Not found (c)	Total (a+c)	Recall [a/(a+c)] x100%	*Precision* [a/(a+b)] x100%
94	6	100	6	100	94 %	94 %

Based on Table 4.6, the recall value is 94%, and the precision value is 94%. Effectiveness is divided into two parts, which are effective, if the value is above 50%, and not effective if the value is lower than 50%. Then the ideal condition of the effectiveness of a text classification system is when the ratio of recall and precision is equal (1: 1) [13]. Thus it can be concluded that the system is effective because the ratio of recall and precision is 1: 1

4. CONCLUSION

Based on the result, it can be concluded that Probabilistic Neural Network (PNN) algorithm can detect the location of vacant or occupied parking spaces in real-time under the determined targets This is supported by an accuracy rate of 94%. Light intensity has an impact on the success of this research. The presence of a sufficient level of sunlight is very helpful to facilitate the system to detect whether the parking space is vacant or not. If the research performed at night, this system will rely on the available lights. The image density or pixel level also affects the success of the system. It also can be concluded that the color of the car affects the success rate, the darker the car color is detected, the greater the risk of system failure.

Further research can be developed by extending the range of the camera to detect more than five parking slots. In addition, the application of shape-based feature extraction can achieve the optimal result. The utilization of Arecont Vision AV10005 Closed Circuit Television (CCTV) camera will ease the system because it is easy to put in a higher location and with good image quality and high pixel level.

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