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Elevator Button and Floor Number Recognition through Hybrid Image Classification Approach for Navigation of Service Robot in Buildings

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Abstract— **To successfully move a robot into the building, the elevator button and elevator floor number detection and recognition can play an important role. It can help a robot move in the building, just as it also can help a visually impaired person who wants to move another floor in the building. Due to vision-based approach, the difference in lighting condition and the complex background are the main obstacles in this research. A hybrid image classification model is presented in this research to overcome all these difficulties. This hybrid model is the combination of histogram of oriented gradients and bag of words models, which later reduces the dimension of image features by using the feature selection algorithm. An artificial neural network has been implemented to get the experimental result by training and testing. In order to get training performance,1000 training image samples have been used and additional 1000 image samples also been used to get the testing performance. The experimental results of this research indicate that this proposed framework is important for real-time implementation to implement the elevator button and elevator floor number recognition framework.**

Keywords— Elevator button and floor number recognition, Image classification, HOG, BoW, Artificial neural network.

I. INTRODUCTION

Elevator buttons and floor number recognition can be one of the main concern for navigation of service robot in buildings [1, 2]. Such an approach could help direct those peoples who are blind or has visionary problems but they want to move freely in the building. A common person can easily accomplish this type of task with his visual ability, though it is a complex work for a robot [3]. Generally, there are two direction buttons exist on the outer panels of the elevator which are upper and lower directions buttons, by pressing those direction buttons, elevator can direct to a particular direction. To accomplish this task, first of all, a robot that comes from outside of the elevator have to detect the elevator button panel and followed by successful recognition of those button to get the sense of which way that robot wants to go, for example either go up or down. The next step is to recognize the floor number from the floor indication display panel of the elevator. Through this floor number recognition, the robot can take the decision for that the elevator is ready for departure or if the elevator is arrived on the desired floor, so the robot can move out from the elevator, or go inside to the elevator.

The current proposed research is very much related to real-time image text detection and classification [4]. Although it is related to real-time text image classification, the elevator's environment completely different from the external environment is one of the reasons for keeping it in a different category. One of the first obstacles to performing this proposed procedure is the complex background and reflection of the light and if those issues not overcome, the desired success will not be available [5]. Another notable obstacle is to give a person the idea of an object is easy as possible, that's a very complex task to a robot [6]. Considering all these issues, the main objective of the current research is to achieve the desired success by eliminating complex backgrounds in the potentially easy way by using a hybrid approach. Through this hybrid image classification approach in this research, using of machine learning algorithm added additional helps to achieve this research successfully. Firstly, the success of this research was determined by the success of the elevator button detection and reconstruction, which would later determine the ultimate success of the floor number detection and recognition of the elevator floor display.

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II. RESEARCH METHODOLOGY

This current proposed research methodology is mainly divided into two main sections, in the interest of presenting the novelty of this proposed research. The first part of this research methodology is the elevator button detection and recognition part and the second part is the floor number detection and reconstruction part of elevator floor display.

A. Elevator Button Detection and Extraction Framework

Firstly, for the elevator button detection and reconciliation an elevator button database is created with the collection of different types of elevators button images, which can be used to determine the performance this proposed research experiments. These images are extracted through real-time video frame extraction process, which can be captured by a low-cost smartphone. At the very beginning of this section, several image pre-processing stages have been used to extract the elevator button images. As a part of image-preprocessing, color thresholding, noise elimination, and elevator button number extraction algorithms are used. In order to bring the variation between the image database, 50% of the image database is synthesized database, which is created by the varying orientation angle of the elevator button images. Firstly, an image that is collected through the camera is converted into grayscale image from the RGB image with the equation number 1.

$$GrayImage = (0.2989 \times R) + (0.8570 \times G) + (0.1140 \times B) \quad (1)$$

After that, this grayscale image is going to the noise elimination algorithm such as the median filter for unwanted background elimination. Then this normalized grayscale image is converted into the binary image and those objects are contained less than 300 pixels value are removed from that binary image, so that the desired elevator buttons can be extracted. Fig. 1 shows the Elevator button detection and extraction framework.

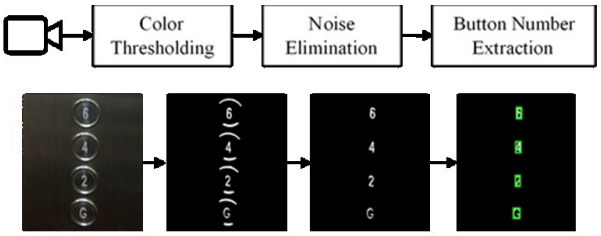

Figure 1. Elevator button detection and extraction framework

B. Elevator Floor Number Detection and Extraction Framework

The second section of this proposed research methodology is to create an elevator floor number database with elevator floor number detection and extraction framework. Generally, the floor numbers of the elevator are the red color, so its detection and extraction process is different than others. Firstly, by the color threshold process, it is extracted only the red color object, which is later extracted to the floor number by normalizing the noise remover algorithm. Fig. 2 shows the Elevator floor number detection and extraction framework.

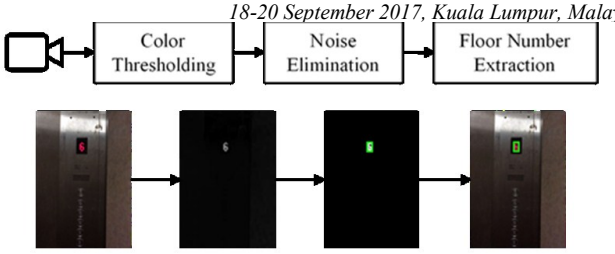

Figure 2. Elevator floor number detection and extraction framework

C. Recognition Framework

The same framework for elevator button and elevator floor number recognition is proposed by this research namely hybrid image classification approach. One of the main reasons for this being called hybrid is that these image classification approaches are composed mainly of two individually image feature extraction methods, namely, histogram of oriented gradients (HOG) and bag-of-words (BoW). HOG and BoW models are very familiar in the field of image classification [7]. Both of these images feature extraction methods produce the image features, which are later made more useful in the feature selection algorithm. Feature selection algorithm is used here to reduce the feature dimension, which is very important for this proposed approach. In this research, InfoGainAttributeEval algorithm is used as a hierarchy attribute evaluator and the Ranker search algorithm is used to search for rankings of image features by using Weka software. HOG extracted many image features which can be reduced by the feature selection algorithm by selecting the best quality 100 features. Just like the other strongest 100 image features selection are made from extracted image features by BoW method. Using the combined 200 image features, the elevator button and the elevator floor number recognition will be done. Table I represent the image feature extraction performance. From here it is seen that the HOG feature extraction process is taking a bit longer time than BoW.

TABLE I. IMAGE FEATURE EXTRACTION PERFORMANCE

Name	Number of Images	Initial Features Dimension	Selected Features Dimension	Processing Time (s)
HOG	2000	2000-by-10404	2000-by-100	18.34±2
BoW	2000	2000-by-2370	2000-by-100	15.77±2

What has been described so far is the first part of the recognition framework. The second part of the recognition framework is to implement an artificial neural network (ANN) that is widely used for the image classification. The 200 image features that are selected will be used as input of this ANN. Based on those input pattern, the artificial neural network can give its decision. Fig. 3 shows an example ANN architecture that has 20 neurons in its input layer, 10 neurons in the hidden layer, and 10 output neurons in the output layer.

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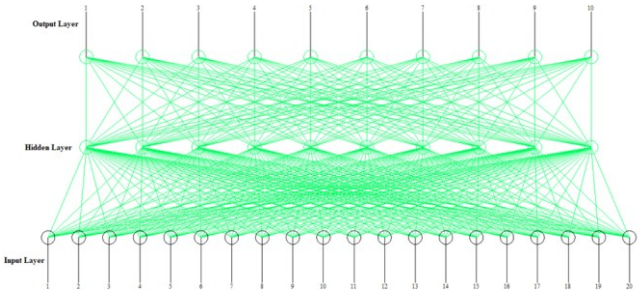

Figure 3. An example architecture of Artificial Neural Network

Firstly, this artificial neural network will be trained, through which it will be useful for testing, which will be used to perform the performance measurement of the image classification of this proposed approach. The ANN that will be used in this research, the number of neurons in its input layer will be 200, the number of hidden layer neurons will be 100, and the number of output layer neurons will be 10. A complete recognition framework for this research is showing in Fig. 4.

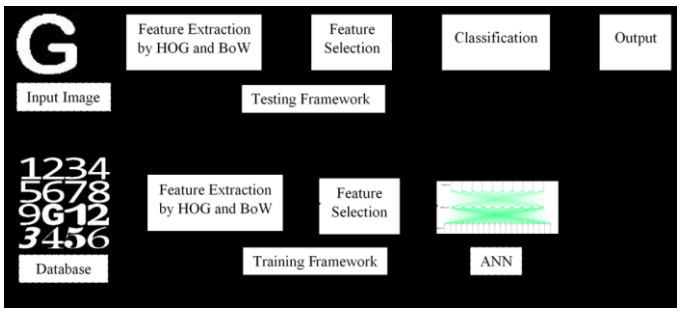

Figure 4. Recognition framework

III. DATABASE DESCRIPTION

The database used in this research has been divided into training and testing database. The data used in the training database will never be used in testing. For the elevator button recognition, a total of 1000 button images has been collected for 10 different classes elevator button and each class has 100 different image samples. Similarly, another 1000 floor number images have also been collected for 10 different elevator floor number recognition. 50% of all these collective images will be used for training purpose and the remaining 50% will be used for testing purposes. To make the images more useful, all the images were brought to the same dimension. The image dimension used in this experiment is 56-by-56 pixels which is useful for this experiment. Fig. 5 shows an example database of elevator button, floor number, and extracted image.

Figure 5. Example elevator button, floor number, and extracted image database

IV. EXPERIMENTAL RESULT AND DISCUSSION

These research experiments have been done through MATLAB 2017a and Weka 3.8 software. MATLAB has been used for image feature extraction and for image classification, on the other hand Weka has been used to reduce image feature dimension. This research can be found mainly combination of two experimental results, they are elevator button recognition and elevator floor number recognition experiment results. This complete experimental result is divided into two main categories, firstly training performance and secondly testing performance and the details are described here.

A. Training Performance

Initially, ANN is being trained to develop a classification model that is suitable for further use. The training is run until the ANN gives the desired output. When ANN got its desired output, then ANN stopped its training process. Fig. 6 shows the ANN training performance. It is seen that in this training performance plot, at the beginning of the training, the cross-entropy error was high, which decreases in epoch 28 near to zero (0.0033779). This kind of training produces better classification results in many research domains.

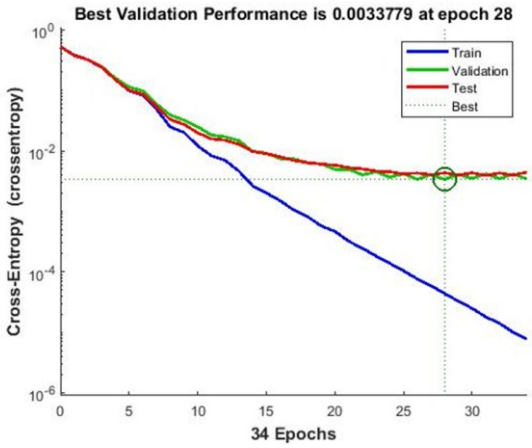

Figure 6. Artificial Neural Network Training Performance

B. Testing Performance

To determine the performance of any ANN, it is very important to test at the end of the training. This research has been trained with 50% of the data and the remaining 50% of the data is tested. Based on the reconnaissance performance of 10 different image classes, this research determines the testing performance. Based on the confusion matrix, the testing result were shown in Fig. 7.

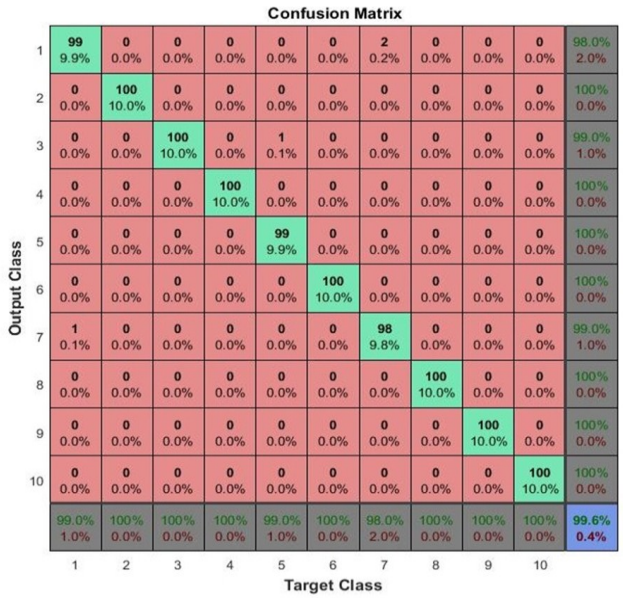

Figure 7. Testing Confusion Matrix

This confusion matrix shows that this proposed hybrid image classification approach is able to accurately classify the 99.60% of elevator button and the elevator floor number. Such a high classification accuracy is very important to the real-time applications. Although there are some wrong classifications, like 1% of the first class incorrectly classified as class 7. Again, in the same way, 2% of class 7 also misclassified with class 1. One of the main reasons for such error classification in class 1 and class 7 is that the image data in class 1 and class 7 is very similar to each other. This type of error is acceptable, because the methodology that is being proposed here is vision based, and the vision based system can produce the wrong decision when the vision parameters match one another.

C. Performance Comparison with Other Machine Learning Algorithms

To present this proposed research novelty more importantly, here in the Table II shows the different machine learning algorithms performance with this proposed research. This comparison result is achieved by using the MATLAB classification learner app. From this comparison, although other machine learning approaches provide a very good result, even then the proposed current research ANN decision model offers the best results.

TABLE II. PERFORMANCE COMPARISON WITH OTHER MACHINE LEARNING ALGORITHMS

Name of the Classifier	Training Time (s)	Accuracy (%)
Tree	27±3	97.00
SVM	25±8	98.26
KNN	28±5	95.88
Ensemble	17±4	98.63
Proposed ANN	7±1	99.60

V. CONCLUSION

This manuscript presented elevator button and floor number recognition by a hybrid image classification approach for navigation of service robot in buildings. This hybrid image classification system showed optimistic performance. The main contribution of this research work is the combination of HOG and BoW image feature extraction with the help of feature selection algorithm to reduce the image feature dimension. The use of artificial neural networks for image classification increases the performance of this research, which is proven by experimental results. Based on the conducted experiments, it can be concluded that this proposed hybrid image classification model is an important contribution in the field of elevator button and elevator floor number recognition. The future work of this research will be implementing an elevator button and elevator floor number database with numerous variations for further experiments to achieve more robustness at the adverse condition.

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