Smart Data Recognition System for Seven Segment LED Display

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Abstract—**The automatic data capturing system provides an alternative and effective way of data collection instead of manual data collection in the laboratory, especially for experiments that need to be carried out for a long period. It can solve common mistakes made by humans, like misreading or mistyping data. Thus, a new smart data recognition system for a seven-segment LED display is developed to sort the whole process of data collection to become more systematic and accurate. An image is captured and saved automatically in an image file, and then it is processed through MATLAB software to identify the digits displayed on the LED display. Once the image is preprocessed, analyzed, and recognized, the final output values obtained are transferred to an existing Excel file for a further process according to the user's requirement. From the results obtained, it was proven that binary thresholding is the best preprocessing method, and the brightness of the image should be set to '0' for better recognition output.**

Keywords—capturing system; image processing; image analysis; image recognition; MATLAB

I. INTRODUCTION

DATA are items that provide an association between humans and the world we study. As a consequence, data holds an important role in all applications of the scientific method and also progress in science, business, and industry. Hence, the quality and accuracy of data have always been a significant target of a venture.

Automatic data capture is a modern method used to obtain graphical data and transform it into an efficient and editable digital format. It detects objects, then collects data and enters it directly into the computer system for further usage, and the whole process does not involve humans. As can be noticed, most of the major losses in operations are affected by the accuracy of data and information. This is primarily due to common mistakes made by humans in the data collecting and recording process. Technicians handling hundreds of tubes, loading samples, and labelling samples can and do make mistakes.

With the development of an automatic data capturing system, it can eliminate wasted space and saves time for collecting, keeping, and filing. Besides, it also helps reduce the expenses on storage rentals and the cost of manpower.

There are many types of automatic data capture, where typical technologies are considered. One of them is the Optical Character Recognition (OCR). OCR is an electronic conversion technique that is used to convert text on an image into machine-encoded text. By 1950, electronic data processing had become an important field as the technological revolution was moving forward at high speed. Data entry was performed through different effective and efficient ways as the amount of data needed had increased. At the same time, technology for machine-reading was becoming

sufficiently mature for application [1]. The early version of the OCR machine had to be trained with images of each character and worked on only one font at a time. But now, the system is more advanced in producing a high degree of recognition accuracy for most fonts.

The data capture system first obtains external data through the capture of an image. Then the image needs to undergo some processes before the data can be recognized by OCR. The methods involved are image preprocessing and image analysis, where all these processes will be run using the MATLAB software with the algorithm implemented.

II. LITERATURE REVIEW

Digital image processing is a new development that started in the sixties when third-generation computers made their appearance. A large quantity of information can be found in an image. Therefore, due to the ability of a computer to process high capacity storage and calculation speeds, it could be used in developing algorithms for processing large numbers of applications.

One of the first fields to use digital processing to enhance images is space research in 1964 at the Jet Propulsion Laboratory in Pasadena, California. It was used to correct camera distortion in the images of the lunar surface to be transmitted back to Earth from the Ranger 7 probes by a computer. After that, many techniques for image enhancement and restoration started to develop in connection with the Surveyor, Mariner, and Apollo missions.

There are practical applications that have been implemented, ranging from medical diagnostics to visual recognition by computer robotics and artificial intelligence fields. It also includes automatic recognition of text of handwriting and license plates [2], and shapes of objects by a machine to replace the use of the human eye [3].

With the rapid development of information technology, digital technology, and microelectronic technology for digital image processing are becoming more and more advanced in terms of the new methods developed. It gathers an image's information acquisition, transmission, storage, transformation, and understanding the content like in reality, and the discipline system to form the richest in the professional field where digital image processing is divided into three levels which include image preprocessing, image analysis and image understanding [1].

Image preprocessing is the operation that is used to improve an image's data from the lowest level of abstraction or enhances some image features, which is important for further processing. At the same time, it will not increase the information content in an image [4].

For image analysis, the steps involved are image segmentation, feature extraction, and classification, which are the processes used to extract useful information from an image. Image segmentation divides an image into multiple segments so that the image is then easier for further analysis.

The most general software used by engineers and scientists in both industry and academia is MATLAB, where it is used to perform numerical computations, develop and test mathematical algorithms and process images with related usage. The data is also displayed in a wide range of different development work. Its image processing application is the greatest; therefore, MATLAB offers a lot of varying image modifications [5].

One of the basic image preprocessing applications that are developed using MATLAB is the car license plate extraction system. One of them is written by P.V. Suryanarayana [6]. The preprocessing image algorithm used in this paper is the Morphology based technique that operates on the preprocessed, edge image of the vehicles. The edge image is generated by performing the Sobel edge detection operation on a grayscale image. Characteristic features such as license plate width and height, character height, and spacing are considered in defining structural elements for the Morphological operations. The connected component analysis is used to select the band containing the license plate from the selected segment. Besides, the research also shows the dependency of the structuring element on the accuracy of the system.

C. Nelson Kennedy Babu [7] also proposed an application regarding license plate localization using the Morphology technique. It is based on the combination of Morphological operation that sensitive to specific shapes in the input image with a good threshold value by which the license plate is located. To detect the vertical edges in the input image, the technique used is the edge features for the license plates and characters. The resultant binary image is produced by counting the number of ON pixels in each row of the image array. The row which contains the highest values is treated as the license plate region. Morphological operations such as dilation and erosion are then processed to remove the unwanted regions and enhance the wanted region. The enhanced region is then extracted.

In the study of various image segmentation algorithms for different types of images by Krishna Kant Singh [8], some specific segmentation algorithms were analyzed with the consideration of the type of input images like the colour image, grayscale image, and a text image. Besides, some segmentation algorithms used for text detection based on difference and similarity features were also discussed. All the algorithms have their strengths and weaknesses. Some cannot be used on samples having similar backgrounds and foregrounds, while others cannot be used due to instability. Lastly, the study concludes that, based on the input image, the algorithm should be chosen to get the best final output result.

Besides that, there is a regularly used method which is Otsu's method. It selects the threshold value by maximizing the between-class variance. A paper is written by Kumar, Pant, and Ray [9] discusses the embedded Differential Evolution (DE) using Otsu's method to select an optimized threshold value. This method is then tested on a set of images, and the results showed the effectiveness of the proposed technique.

TABLE I. COMPARISON OF DIFFERENT IMAGE PROCESSING METHODS

Title	Method	Strength	Weakness
Efficient Fuzzy Edge Detection Using Successive Otsu's Method [10]	Successive Otsu's Method	-Able to enhance the performance of Classical Sobel Edge Detector up to the level of standard Canny Edge Detector.	-
Using Morphological Operations-Erosion Based Algorithm for Edge Detection [11]	Morphological	-Accurate positioning -Computation time which suitable to use in real-time -Able to produce one-pixel-width continuous edges	-Complexity of the algorithm -More steps involved
Image Segmentation Based on Multiple Means Using Class Division Method [12]	Class Division Method	-Better identifies fine structures of objects in complex images -Low computational cost -Reduce computational time	-
A Novel Design For Vehicle License Plate Detection and Recognition [13]	Hough Transform	-Reduce computational time	-

Besides, another paper written by Gautam and Ahmed [10] was on the fuzzy-based edge detection using Successive Otsu's method. In this paper, the algorithm of this method is described and utilized in a grouping image histogram into different partitions. The algorithm developed is used to provide the threshold parameter to the classical Sobel Operation to enhance its edge detection capability using fuzzy logic. The final results are then compared with the Canny Edge Detector. Other image processing methods with its strengths and weaknesses are as summarized in Table I.

III. METHODOLOGY

To acquire the data from an LED display, the first step is to construct a simple seven-segment LED display circuit that also consists of a 4-digit up counter. Then, the circuit is combined with a webcam for capturing purposes. To make the whole system function automatically, the webcam is set to capture automatically. The image captured is saved into a folder on the computer.

After obtaining the external data through the captured image, the image saved is used for image processing to recognize the digit numbers using the algorithm implemented in MATLAB. The flow of the process is shown in Fig. 1.
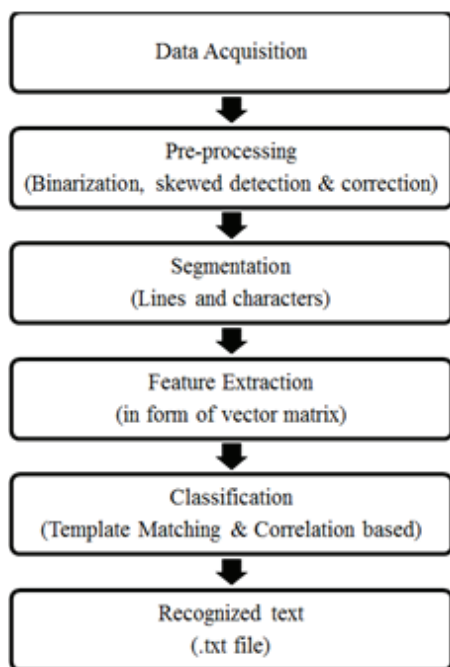

Fig. 1. Block diagram of image processing.

The technique used for preprocessing in this paper is simple thresholding. From a grayscale image, thresholding can be used to create a binary image. Hence, the coloured RGB image is converted to grayscale using the command *rgb2gray*. The size of the image is determined by the number of rows and columns. A zero image is then created by the rows and columns array of the grayscale image. Then only the thresholding is performed on the image with the MATLAB code as follows:

```
for i=1:r
    for j=1:c
        if I(i,j)>105
    im(i,j)=1;
        end
    end
end
```

After the image is converted to binary, all small objects are removed from it using the command *bwareaopen*. Once the preprocessing of the image is completed, the following step is image analysis. The steps involved are image segmentation and cropping, which is the process of extracting meaningful information from an image. Segmentation subdivides an image into its constituent regions or objects. The level to which the subdivision is carried depends on the problem being solved. That is, segmentation should stop when the objects of interest in an application have been isolated.

The number segmentation is done using blob analysis, which involves the command *bwlabel*. This command labels and gives the number of pixels connected in a sequence to form a group of connected objects. Then, the line matrix function is applied to the algorithm that takes the binary image. A row in the image with no object and consist only black pixels is then split along this line. All of the empty areas around the objects are cropped in another sub-function called a clip.

To recognize the seven-segment digit numbers in the image, a template matching is applied in this part. A template is created at the beginning of this step using all the sample images of each digit after isolation, which are cropped into a .bmp file with a constant size of 50×70 using *mat2cell*. There is a requirement of a single array containing all digit numbers so that all the numbers may be compared using a single loop. Otherwise, long coding would be required for correlation. By using a multi-dimensional array, the binary information is saved. This is done using the *mat2cell* function, where the multi-dimensional matrix is converted to a cell with the same data stored.

Then, a function named *read_letter* is created to compare the input digit and the template with the uses of the correlation function. A *for* loop is generated in the algorithm, starting with the first loop and incremented by 1 for each successive loop until the last digit in the image is reached. After that, the 2D correlation coefficient matrix of the input image is computed with the matrix in the template using the function *corr2*. The correlation coefficient is appended to the

array using horizontal concatenation, and then a comparison is made with the template to find out the matched digit.

Finally, after the seven-segment digit numbers are successfully recognized using the MATLAB algorithm, data is transferred and saved in an existing Excel file for further usage using *xlswrite* command. At first, the Excel file is read by the MATLAB using *xlsread* command to identify the currently available row in column A to insert the data. This medium will cause any old data is not updated whenever new information entered.

IV. RESULTS

The final output the hardware construction is shown in Fig. 2. The step-by-step construction is beyond the scope of this paper.
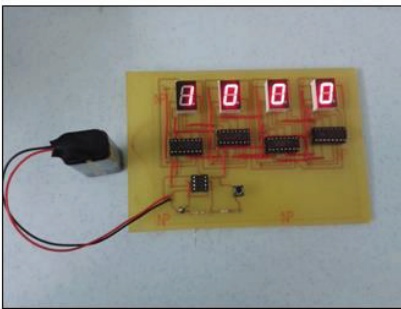

Fig. 2. The final output of the hardware result.

In the software result, different algorithms and methods are used to test image processing. Finally, thresholding is chosen as it produced the best binary image. Three methods were tested, which included Otsu's, Morphological, and Thresholding. For Otsu's method, the *graythresh* command is used. While for the Morphological method, it is more complicated, and more steps were involved where it at first needed a setup of a structural element for the process to carry out. Then, the action followed by dilation and erosion.

Fig. 3 shows the difference between the final output binary image of each method. As for Otsu's method in Fig. 3(a), the result is quite the same as the Morphological method but there is an extra white region in the binary image.

For the Morphological approach in Fig. 3(b), although the numbers are shown are clearer than Otsu's method and there is no other white region. The background is fully black, but as the holes of the number are filled which may cause a recognition problem for number 0 and 8. After the *imfill* command is used, both numbers 0 and 8 are the same. So, recognition fails.

(a) Otsu's method   (b) Morphological method
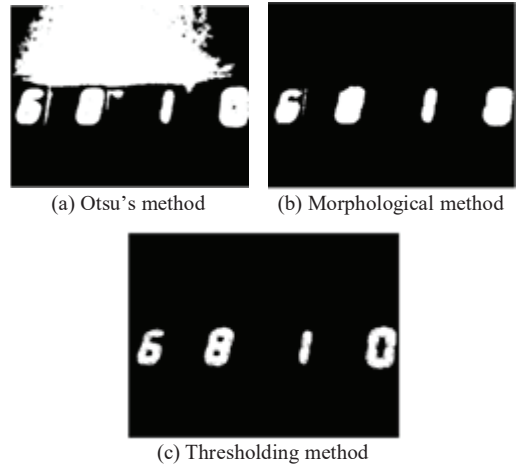

(c) Thresholding method

Fig. 3. The output of the binary image using a different method.

But for thresholding in Fig. 3(c), the holes of the number are not filled up, and the objects and background are clearly shown. As a result, every number can be differentiated and recognized very well. Thus, the accuracy is much higher compared to the other two methods. Therefore, this method of image preprocessing is selected. The result of image processing is also affected by the brightness of the webcam. Therefore, the intensity was adjusted until the best image processing result is produced. Finally, the brightness is set to 0 and the best binary image is provided with no other unwanted objects.

If the brightness of the image is set too high, the final result received is inaccurate, and the digit number reading may be different from what is shown in the input image. Fig. 4 shows an example of a failed image processing and recognition when the brightness of the image set to 50. There are still many unwanted objects after going through several stages of image preprocessing, causing the final recognition to go wrong. Although the input image has only

4 digits, the final recognition as shown in Fig. 4(d) shows that the system recognized 8 digits instead of 4 digits. This is because 8 objects were detected in the image segmentation and cropping part in Fig. 4(c).

(a) Original image   (b) Binary image

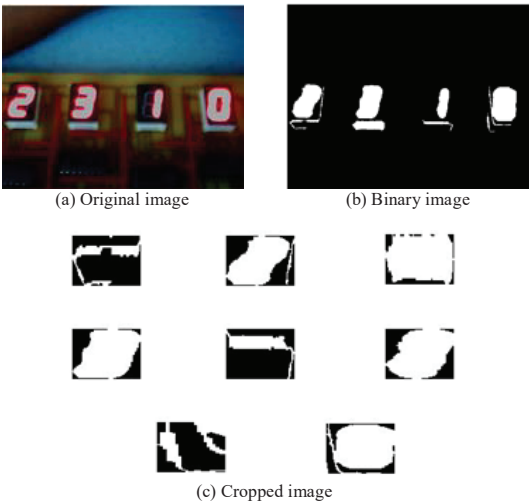(c) Cropped image

(d) Final result in Excel

Fig. 4. Sample of failure recognition with brightness 50.

A Graphical User Interface (GUI) is designed and created in MATLAB, as shown in Fig. 5. There are 3 push buttons in the GUI. The first button is to load an image from the image stored file, and the second button is to convert the original image to a binary image. The final button is to get the recognized data shown in an output message outbox. At the same time, the identified data is exported to an existing Excel file and saved. The axes box created is used to display the image.
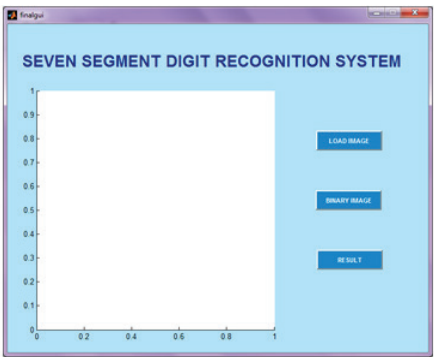
Fig. 5. The layout of the GUI.

Table II shows the methods of image preprocessing, with the binary thresholding method, recorded the highest accuracy. Three out of three images were recognized correctly. Thus, this shows that the binary thresholding method is the most suitable method to use for the preprocessing of 7-segments LED display images.

TABLE II. DATA ANALYSING PROCESS USING DIFFERENT IMAGE PROCESSING METHOD

Method	Digit (Input Image)	Digit (Recognized Output)	Accuracy (%)
Otsu's	2319	112315	
	5139	115139	33.33
	4179	4179	
Morphological	2319	2319	
	5139	5135	83.33
	4179	4175	
Thresholding	2319	2319	
	5139	5139	99.99
	4179	4179	

As Table III shows, the correct output result will only be obtained when the brightness is set equal to 0, while the other brightness levels produced the wrong results. This shows that the lower the image brightness, the more accurate the output result.

TABLE III. THE COMPARISON OF THE RESULT WITH DIFFERENT IMAGE BRIGHTNESS

Digit (Input Image)	Image Brightness	Digit (Recognized Output)
5139	100	1151135
	50	51139
	0	5139
6249	100	182149
	50	81245
	0	6249
7549	100	171549
	50	75148
	0	7549

V. CONCLUSION

In conclusion, a simple up counter hardware circuits are built to demonstrate the seven segments LED display together with the webcam for automatic capturing purposes. The entire algorithm in MATLAB is integrated into a system, and a GUI is also designed. The digits shown in the form of 7-segments are recognized by the system correctly and transferred into an existing Excel file. The system can operate as expected with some limitations for future development and enhancement. In conclusion, the best preprocessing method is binary thresholding, and the image brightness should be set to '0' for better-recognized outputs.

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