Indonesian Journal of Computer Science
ISSN 2549-7286 (*online*)
Jln. Khatib Sulaiman Dalam No. 1, Padang, Indonesia
Website: ijcs.stmikindonesia.ac.id | E-mail: ijcs@stmikindonesia.ac.id

Digit Recognition Using Local Projection Dependent Clustering

Rizka Rahayu Sasmita[1], Aliridho Barakbah[2], Achmad Basuki[3]
[1]rizkarahayu42@gmail.com, [2]ridho@pens.ac.id, [3] basuki@pens.ac.id
Politeknik Elektronika Negeri Surabaya

Article Information

Submitted : 21 May 2023
Reviewed: 11 Jun 2023
Accepted : 27 Jun 2023

Keywords

Water Meter Image; Local Projection; Image Processing; Neural Network

Abstract

Water companies utilize water meters to measure and calculate water usage bills. However, the current process employed by PDAM requires redundant resources, as it involves taking photos of each customer's house and having other officers read the numbers from the water meter images, resulting in inefficiency. The problem is further compounded by the neglect and improper maintenance of water meters, with some being buried in garbage or soil. Additionally, officers contribute to the challenges by capturing blurry and tilted photos, hindering the accurate reading of the water meter numbers. This study applies a water meter reading system by processing water meter photos and converting them into text using image processing methods to process images and Neural Networks to perform digit recognition. The image processing process includes steps such as (1) grayscale conversion, (2) gamma correction, (3) x-Histogram Projection, (4) White Temporal Ascent Accumulation, and (5) Peak Identification. Furthermore, image segmentation techniques are applied to enhance image quality and eliminate noise using clustering methods. The segmented images are then processed by a neural network to recognize the meter digits. The system achieves a digit recognition accuracy of 75.2%, despite encountering various technical and non-technical challenges during the water meter photo capture process.

A. Introduction

A water meter is a discharge measuring device installed in a piping network for drinking or clean water used by customers and is accurate according to specific requirements [1]. Water companies in Indonesia still use conventional analog water meters to provide measurable and objective clean water services to the community [1]. Water meters are essential for pure water providers because they can continuously track the customer's water usage and inform the customer's water usage bill to the clean water provider [2].

PDAM is the Regional Drinking Water Company, a regionally owned business unit that distributes clean water to the general public. PDAM uses Water Meters to monitor customer water usage and calculate customer water bills [3]. However, in its operation, the PDAM still needs resources that work twice to check and record the water meter from door to door by PDAM officers. One officer visits the customer's house and captures a photo of the customer's Water Meter. In a different location, another officer records and reads the numbers from the Water Meter photo taken by the visiting officer. This process is time-consuming, expensive, and inefficient [3]. Additionally, the condition of the water meter, which is not properly maintained, adds to the difficulty of reading the water meter. Factors such as non-technical issues (e.g., water meter buried in garbage, buildings, soil, or obstructed by fallen plants) and technical aspects caused by officials (e.g., capturing blurry photos, shaky photos, or tilted water meter photos) contribute to these challenges. Consequently, these problems make it difficult to read the water meter numbers accurately and can result in errors in water meter readings [2]. Mistakes in recording and reading the water meter can result in water usage bills that are billed too high or too low, which can be detrimental to customers or companies [2].

Previously, several research and technologies, such as image processing, machine learning, and computer vision, were used to solve the problem of reading meter numbers, such as reading vehicle license plates using an Android device and water and electricity meter reading systems. Previous studies used image processing techniques to cut meter plates and reduce noise and used OCR Tesseract to recognize meter numbers [4]. DO et al. trying to apply CNN method to perform image processing to perform digit recognition; his research can read water meter numbers with high accuracy, but some previous studies of the system can only be run using devices with high specifications because, on average they use the CNN method while in practice, water meter number recorders in Indonesia use mobile devices (Android) with specifications low device [4].

Therefore, an appropriate technological approach and solution are needed to record water meter numbers where the system created can be implemented and run on the Android platform with low specifications so that the system is designed in a method that does not require high equipment specifications when running the meter number recording system. In this study, the authors developed a water meter number recording system using the local projection-dependent clustering method to obtain a system that can detect water meter photos with all conditions of water meter photo problems. This study aims to ensure that in the application of recording the water meter number, PDAM officers no longer register the water meter number twice, namely by taking a photo of the water meter and other officers recording the results of the image. However, with this application system, officers only need to photograph the meter number once. Where the results of the idea of the water meter number will be converted into text, and the text of the meter number will be stored in the system database so that the registrant of the water meter number will no longer re-record images into text water meter numbers manually.

B. Research Method

In general, this research employs the image processing method to enhance the image of the water meter number, while a neural network is utilized to recognize the digit values within the PDAM meter number. Multiple image processing techniques are implemented to address the various issues present in the water meter number image. Each stage of these techniques will be elucidated in the subsequent sections.

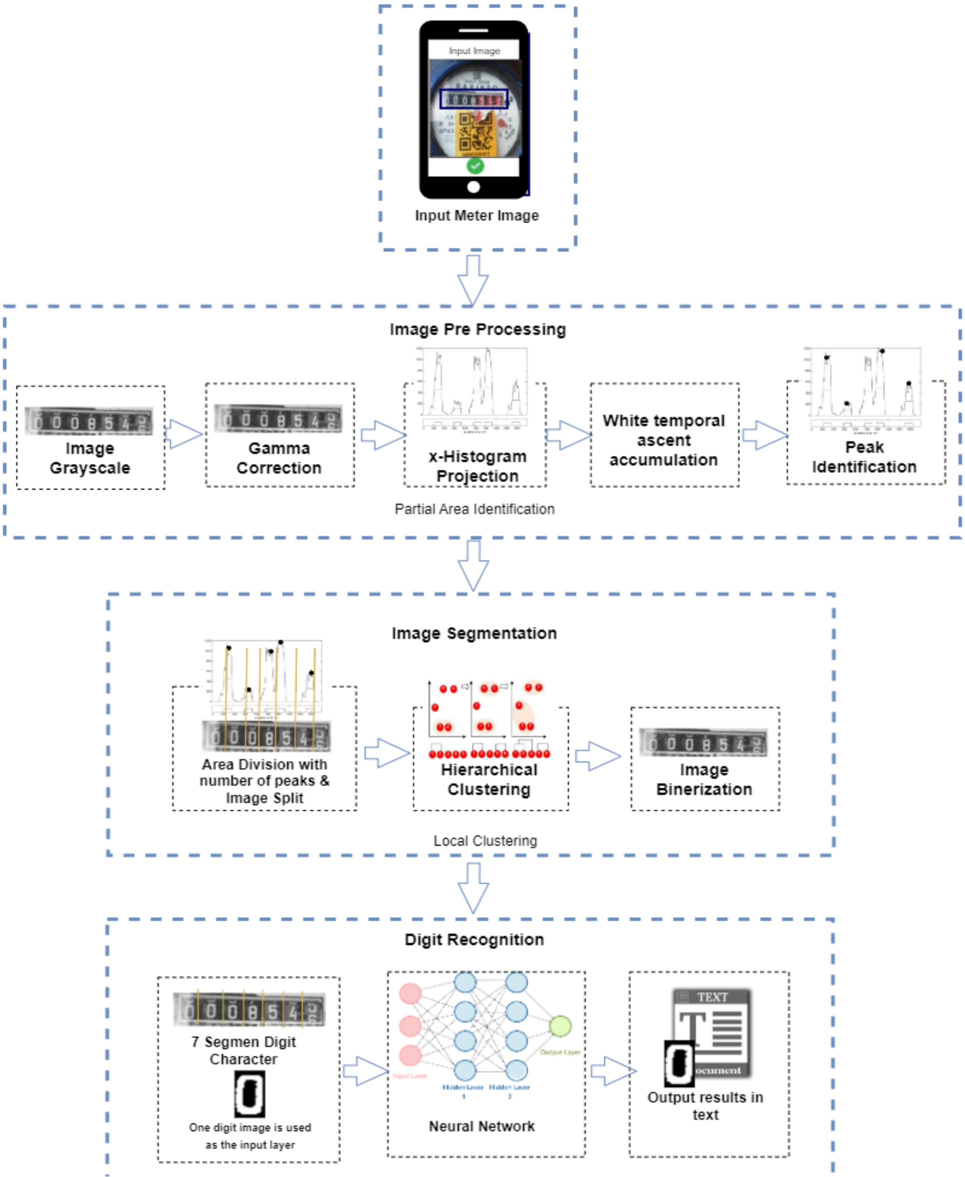


Figure 1. System Design

In Figure 1, the proposed system design is divided into three main stages: pre-processing the water meter digit images, then segmenting the image, and continuing with the digit recognition stage until the system can recognize the meter digits and store them in text form.

a. Data Collection

The data used in this study are photos of water meters with an analog model taken by PDAM Surabaya officers from every house. Photo data that has been collected by the company is provided to the author for system requirements so that it is not open access. The water meter photo data looks like in Figure 2

Figure 2. Sample photo of PDAM water meter number

We manually crop the sample photo of meter data in Figure 2 one by one using photo editor tools to select only the meter number digit area, as depicted in Figure 3.

Figure 3. PDAM Meter Photo Data that Has Been Cropped

The water meter photo sample data shown in Figure 3 is the result of the cropping process on the water meter photo, which is cut only in areas that offer water meter numbers because only the digit part of the water meter number will be processed, which is shown in Figure 3. The data resulting from the cropped area is stored and will serve as training data for training the model to recognize new data (testing data).

b. Image Pre-processing

Before carrying out digit recognition in many case studies of number recognition systems, many researchers carry out image pre-processing processes. Image pre-processing is a method for converting dirty image data (there is noise) into clean image data. The purpose of implementing image pre-processing is to improve some essential features of the image [9], or it can be used to improve the quality of the raw image [6]. Image pre-processing is implemented before performing feature extraction or image classification processes. Applying a good image pre-processing method can overcome problems that produce better global and local features of images and can improve image degradation [9].

The first stage of processing the image of the water meter number is pre-processing; this stage is used to clean the image data and look for the digit area on the meter number. The methods used in this image processing process are grayscale image, gamma correction, x-Histogram projection, white temporal ascent accumulation, and peak identification. Image pre-processing is applied to improve the quality of the water meter image, which tends to have many problems when taking pictures, as well as identifying areas from the PDAM meter digits so that it is hoped that at the image digit recognition stage, it will be easier and more accurate to recognize.

1) Image Grayscale

The captured water meter images undergo conversion into grayscale images, which is essential for the feature extraction process and enhances processing speed. Grayscale images consist of 8-bit grayscale values, eliminating hue and saturation information while preserving luminance. These grayscale images are commonly perceived as black-and-white or monochrome, but they encompass a range of black-and-white values that differentiate them from pure black-and-white images lacking gray levels. Grayscale images exhibit various levels of gray, with contrast spanning from black (minimum intensity) to white (maximum intensity). Originally, the PDAM meter image was in the RGB color space, and the transformation into grayscale form is accomplished using formula 1.

$$Lu = 0.229 * R + 0.587 * G + 0.114 * B \quad (1)$$

R, G, and B values are the Red, Green, and Black pixels of the RGB image color space.

2) Gamma Correction

Gamma correction is a nonlinear operation that encodes and decodes luminance values (light intensity) in an image or video. The lighting level or brightness of a water meter number image has non-uniform lighting in one water meter image, so applying gamma correction is used to expand the histogram of the gray level of the meter number image so that it is hoped that it can improve the lighting in water meter number images that have not white pixel values uniform when done grayscale and binarization.

3) x-Histogram Projection

x-Histogram Projection, in this process, the water meter photo pixels are projected in a histogram in the x direction or the standing order for each segmented line. The projection histogram will calculate the image's white pixel value, determining where the digit position is in the meter number line [11]. The x-Histogram projection stage suggests getting the digit area marked white pixel value in the image to scan the digit area. This process marks the digits vertically from left to right. Furthermore, the meter number image will be cut based on the number of digits on the water meter [7]. This marking area is necessary because of customers' various models of water meters. The result of the projection histogram will be used to crop the digit area, which will later be normalized for digits with a less visible white pixel color. The results of the projection histogram plot will be processed with the accumulation of white temporal ascent to obtain white pixel segmentation in the image.

4) White Temporal Ascent Accumulation

The white pixel histogram projection value will be accumulated to get the peak value of the histogram projection. This process will scan the image of the number area by taking the white pixel value and continuously storing the white pixel value to find the white pixel range value. In this case, it will be calculated and accumulated. The accumulated value of white pixels will be considered as the peak value but will be grounded to 0 in the histogram projection if it encounters a black pixel value, just like the vertical projection proposed by Elrefai et al.[7], the process will continue to traverse each pixel column by column, and if it finds a black pixel, it will count the previously visible groups of white pixels; after that it will move to the next column.

5) Peak Identification

The accumulated white pixel value collected and obtained from the White Temporal Ascent Accumulation process will be the highest peak value indicating the number of white pixels in each water meter image digit. The result of the peak value is used to identify the digit area on the meter number, which is used for localization of the meter number digit area so that it is used as a cutting marker for the meter number digit area.

c. Image Segmentation

This image segmentation stage is applied to digit images separated from other digits in the water meter number image. The peak value that has been obtained previously will be used for the process of dividing the meter number digit area. Then the digit image obtained will be color segmented with hierarchical clustering into two clusters, namely black and white, so that this process will produce a binary per digit meter number image, making it easier for digit recognition of the meter number image is inputted to the system.

d. Digit Recognition

Optical character recognition (OCR) converts handwritten or typed images into machine-encoded text [6]. The mention of digits uses the OCR concept so that the numbers on the water meter can be read with the OCR system through an image processing process. The numbers on the water meter are taken using a camera, and image-based processing is carried out to be recognized using the OCR method and produces output in the form of text. Researchers in related studies [8],[4] used the convolutional neural network method, while researchers [6],[7] used template matching to perform digit character recognition.

The Neural Network method is a network of a group of small processing units that are modeled based on the human nervous system [16].

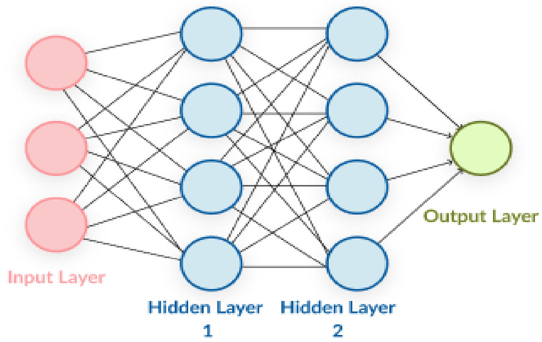


Figure 4. Neural Network Model Overview

Based on the network pattern model illustrated in Figure 4, it can be observed that multiple interconnected neurons are present in each layer. The neural network model comprises three layers: the input layer, the hidden layer, and the output layer. This number recognition stage uses the neural network method by inputting image data per digit (one by one digit) from the image with a total of 7 or 6-digit segments in the water meter number image.

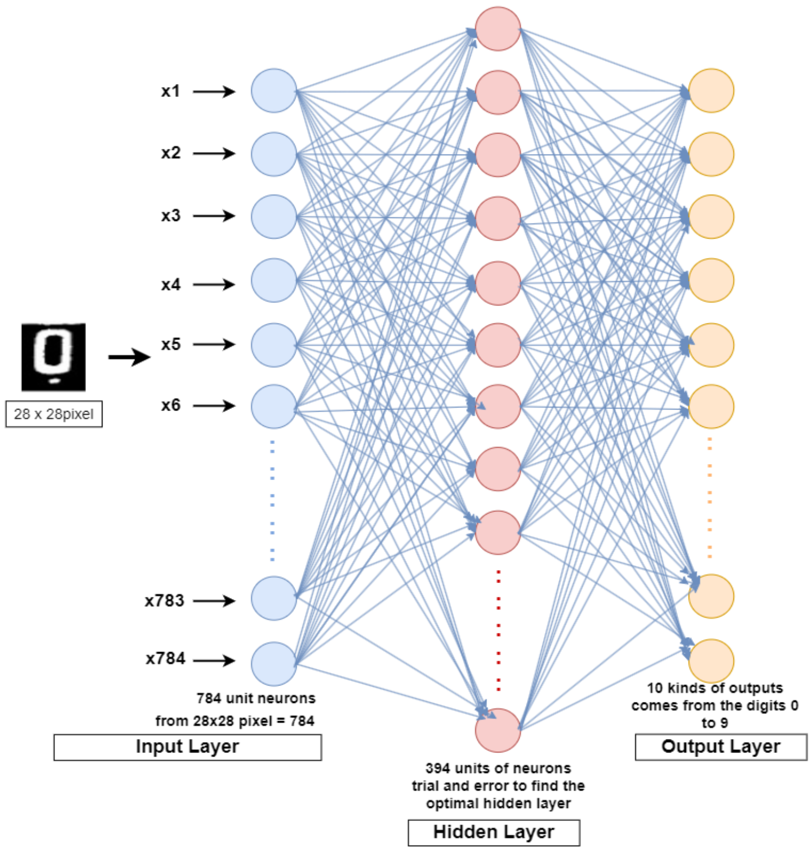


Figure 5. Artificial Neural Network Architecture

To build a network model and prepare image data input for the water meter number done with image processing and image segmentation, Figure 5 is the model's architecture that will be built and trained with training data. In the architecture of Figure 5, there are three layers used, namely:

1. Input Layer
   The input layer in the model above uses 394 neuron units. 394 is obtained from the number of image pixels extracted from each water meter digit image measuring 28 x 28 pixels and arranged as one line in the input vector. This input vector is then given as input to the input layer. The input layer in the neural network architecture consists of 784 neurons, each representing each vector pixel value for the entire data sample used in model training.
2. Hidden Layer
   There is no definite formula to determine the optimal number of neurons in the hidden layer. This paper uses a cross-validation technique to estimate and find the possible number of hidden layer neurons that give the best accuracy results.
3. Output Layer
   The target for all sample datasets used is one vector row in size with each digit from 0 to 9, then used as the number of neurons in the output layer so that the output layer consists of 10 neurons representing ten digits numbers from 0 to 9.

C. Result and Discussion

This section presents the results of the research design and implementation of image processing and neural network methods on the system to recognize the digits on the water meter number and store the recognition results in the database. The procedure begins by collecting data and selecting water meter number image data to be used as a training dataset. Then perform image processing which consists of image pre-processing and image segmentation. The final stage is to create a digit recognition model to train the dataset and test the results of the classification model to recognize digit numbers on the water meter number.

a. Implementation of Image Pre-Processing

The first method applied to the PDAM meter number image is the Conversion of RGB water meter Images to Grayscale Imagery. RGB images have pixel intensity values composed of three color channels: red, green, and blue. In contrast, grayscale images are images whose pixel intensity values are based on the degree of gray so that there will be white, black, and gray colors.

Table 1. Change of The Original Image into Grayscale Image

Original PDAM meter image	**Grayscale image**
	

An RGB image successfully converted to a grayscale image in Table 1 will display an image with only a range of white, black, and gray colors. The water meter number images that have been collected have non-uniform lighting or brightness levels, so the gamma correction method is applied to overcome the problem of images having different brightness levels, as shown in Table 2.

Table 2. Grayscale Image Change to Gamma Correction

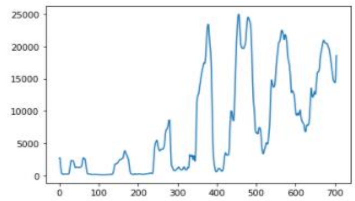
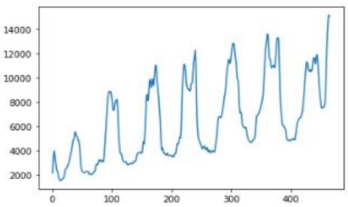
Grayscale Image	Gamma Correction Image
	
	

Table 2 displays the results of changes from the original water meter image to the gamma correction image. The sample image data in rows 1 and 2 of Table 2, shows that there is a change where white pixels are more clearly visible after applying gamma correction.

Applying gamma correction will expand the histogram of the gray level of the meter number image to improve the luminance in the water meter number image, which has non-uniform white pixel values when grayscale and binarization are performed.

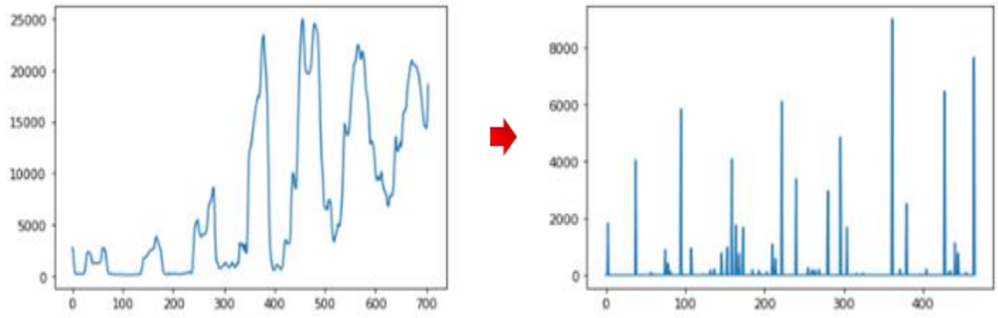
The x-Histogram Projection stage is the process of identifying or knowing the digit area of the meter number. The results of this area identification are used to determine cutting the digit area into images per digit number. Images of water meters that have been grayscale or done with gamma correction will be processed to get the x-Histogram value. This x-Histogram projection will project the white pixel value from the image into the histogram.

Table 3. x-Histogram Projection Graph

Experiment	Result of x-Histogram Projection Graph
	
	

Graph of x-Histogram Projection results in Table 3. It displays the white pixel value so that it can be seen when the meter digit image is white, and the brighter the histogram projection goes up and higher if the white pixel image looks bright.

After obtaining the x-Histogram Projection value, the white pixel values will be accumulated and projected onto the graph as the peak value of the total white pixels accumulated, as shown in Figure 6 below



(a) (b)

Figure 6. (a) x-Histogram Projection Graph, (b) Graph of Accumulation of White Pixels

Figure 6 is the accumulation of white pixels in a graph obtained from the accumulation of white pixels from the x-Histogram Projection values. This process will scan the image of the number area projected on the x-Histogram to take the white pixel value; each time it finds a white pixel value, it will be accumulated, and the accumulated result is stored as a peak value, but if it finds a black pixel it will be grounded to a value of 0.

The accumulation graph shown in Figure 6(b) seeks its peak value as a peak identification process to search for and identify the value or peak point from the result of the accumulation of white pixels in an image of the meter number inputted to the system.

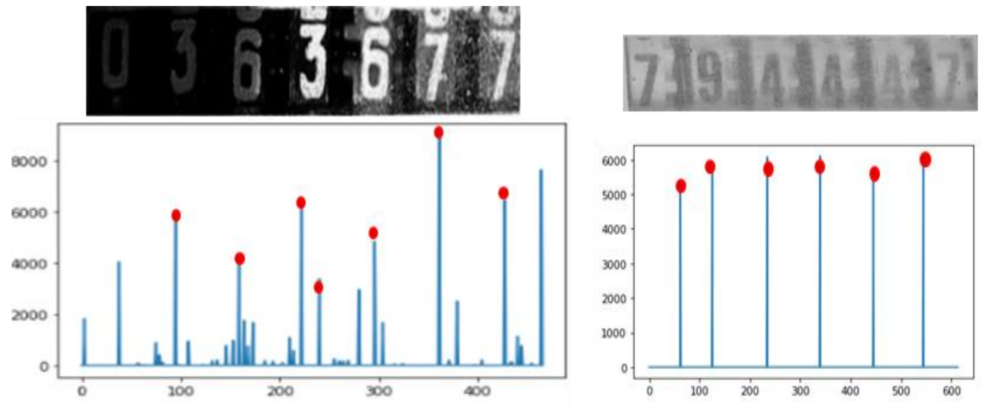


Figure 7. Identify the Peak accumulation of White Pixels

Figure 7 shows the accumulated white pixel values that have been identified as peak values; this peak value will divide the local image area of the same size, which will later be used to cut or separate one digit from another, as shown in Table 4.

Table 4. Peak Value Identification Result

Image of PDAM Water Meter	Peak Number Detection Results
	Jumlah Peak = 7
	Jumlah Peak = 6

Table 4 displays the type of meter model that has a different number of digits in each image number water meters.

b. Implementation of Image Segmentation

The Image segmentation stage is successful if the water meter number image processed in image pre-processing can be binary properly, with only black and white binary pixels. This process normalizes the pixels, which aims to generalize if there is an image result where the white pixel value on the digits of the meter is less visible so that the white pixel values can later be uniformed and so that it is easier to recognize the numbers. To normalize the image, feature extraction is used based on the image's color. A hierarchical clustering method is used to remove the noise in the picture, before performing image segmentation, there needs to be a process of dividing and cutting the meter number digit area, based on the previous method, as shown in Table 4, the peak value that has been obtained from the area identification process is used to divide the area of the meter number to be cut into an image per digit which the process is shown in figure 8.

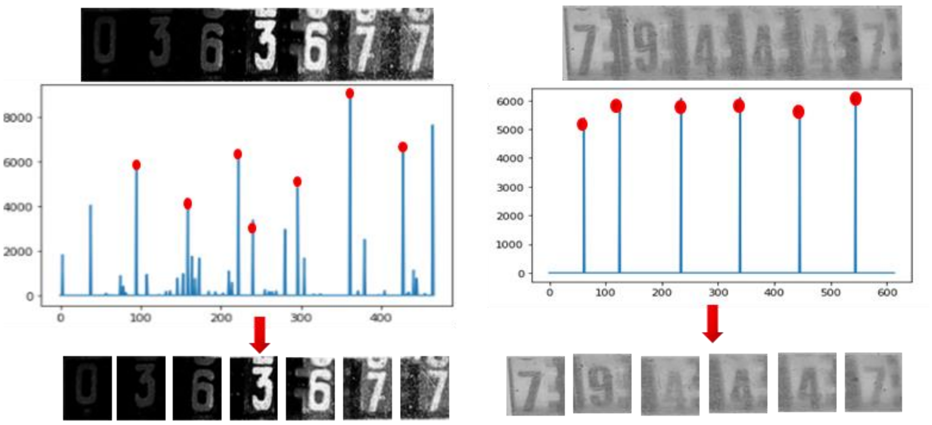


Figure 8. (a) Meter Digit Area cut with 7 Digit Model,
(b) Meter Digit Area Cut with 6 Digit Model

The obtained peaks serve as a reference for determining the equal width of the images to be cropped. This is because the digits of the water meter are uniformly spaced, resulting in digits of the same size for each number. They are cut according to the peaks obtained and identified in the previous process.

The meter number image divided into digit images is processed using hierarchical clustering for color segmentation.

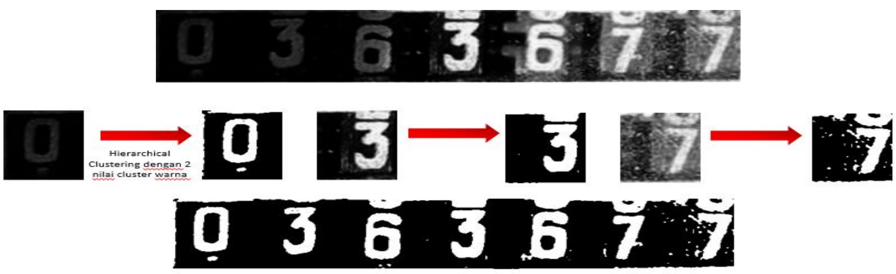


Figure 9. Color segmentation with Hierarchical Clustering

Color segmentation by clustering using 2 clusters based on black and white in this process can normalize digits whose white pixel values are not uniform to be more visible. The clustered image results can produce a good binary image (black and white image), facilitating the recognition stage because the digits in the picture are more clearly visible. In Figure 9, digit number 7 has varying brightness levels and white pixels so that pixel values close to white will enter a white cluster, and dealing with pixels close to black or gray will join the black group. This is in the image segmentation process using the clustering method; images can be separated between the foreground and background, where the foreground or main idea that shows the digits in the picture is marked with a white pixel color. In contrast, all background digit images used as input for the digit recognition system are marked with black pixel color.

The process for repairing this image is included in the local projection method by applying the clustering method to remove noise and disturbances in images that shooting conditions can cause. This technique also improves the sharpness of the image results by removing noise and blurring fine details because the image pixels are clustered into black-and-white pixels only. During the process of changing the binary image, there is less subtle noise, so the method can be used to cluster fine pixels that are not black and white pixels to be converted into black and white pixels according to the value of the cluster.

c. Feature Extraction

PDAM meter number data collected and processed at the image processing and image segmentation stages produces an image per digit number separated from the meter number in a single picture of the water meter number.

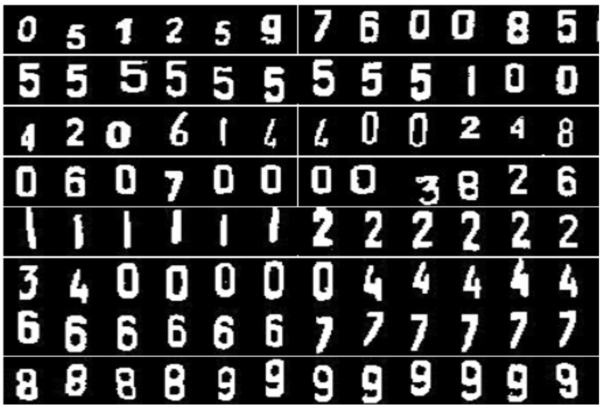


Figure 10. Sample Image for Training Data

We use the meter number digit image in Fig.10 as training data. To prepare the meter number image for training, we perform a feature extraction process and store the extracted features from each digit image, along with the label or target of the digit image, as training metadata in the form of a CSV file.

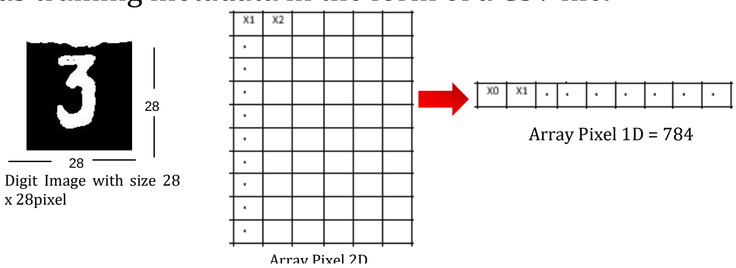


Figure 11. Illustration of Digit Image Feature Extraction

The digit images used as training data will be feature extracted by taking the black and white image pixel values for each digit image and storing them in a 1D array; the pixel values for all digit image data are stored in CSV format. The extraction feature of digit images is illustrated in Figure 11. The extracted digit images are binary digit images with a size of 28x28 pixels, so all pictures of the training data will be resized first to the same size, namely 28x28 pixels. The image is composed of a 2D array, requiring it to be transformed into a 1D vector array. This conversion entails condensing the pixel values from a 2D array with dimensions of 28x28 pixels into a 1D vector array of size 784, encompassing the essential information of the pixels comprising the water meter digit image.

Each digit's 1D array, derived from all training data images, will be consolidated with their respective label values. The resulting collection of 1D arrays, along with the labels, will be stored in a CSV file. This CSV file serves as the data for training the Neural Network model. It contains 784 features obtained from the feature extraction of the image digits, with each image digit associated with a single target value. These 784 unit features serve as the input layers, while the 10 class labels are employed as the output layers during the training of the Neural Network model.

d. Learning Stage

In this study, because the data has many features (multidimensional), the research problem was solved using the Multilayer Perceptron Neural Network Model, which means that solving the problem is not only solved with a linear dividing line between class label one and class label 2. The neural network model has several parameters for solving nonlinear problems; setting parameters such as selecting the activation function, setting hidden unit values in the hidden layer, setting bias values, and learning rates can be used to obtain a good Neural Network model structure [19].

From the results of giving different hidden unit parameters that affect the results of accuracy, in the second remote unit, 394 units were obtained using formula (2), which got a fairly high accuracy value at epoch 10000 with a learning rate of 0.001.

$$m = \frac{n+k}{2}$$

m = *hidden unit*
n = *the number of unit of the input layer*
k = *the number of unit of the output layer* (2)

Table 5. Performance Result of Neural Network Model Training

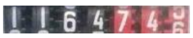
Hidden Unit	No Iterasi	Learning Rate	Accuracy	Error	MSE
15	5000	0.1	94.89%	5.11%	0.0511
	10000	0.1	95.59%	3.41%	0.0344
394	5000	0.1	95.7%	4.3%	0.043
	10000	0.1	96.46%	3.54%	0.0354
	10000	0.001	98.23%	1.77%	0.0177
405	5000	0.1	96.08%	3.92%	0.0392
	10000	0.1	95.58%	4.42%	0.0443

From the observations in Table 5, the value of the accuracy of the training model, error value, and MSE, the model can do well learning using the prepared training data with a reasonably high accuracy value of 98.23% when using a hidden unit of 394 neurons, at epoch 10000 with the learning rate applied to the model is 0.001, but in model learning the high accuracy value has not determined that the model can do good number recognition, sometimes the model can get stuck in overfitting or under fitting conditions, so it is necessary to test it with new testing data.

e. System Testing

Testing the learning model system is carried out at this stage using new testing data. The model used is a model with a neural network parameter structure that obtains high accuracy based on table 5, namely by using a hidden unit of 394 neurons, with 10000 epoch iterations and a learning rate set at 0.001. The system test results are shown in Table 6.

Table 6. Testing Result

No	Image of water meter	Original Number	Recognition Results	Error	% Error
1		2 1 7 7 8 1 2	2 1 7 7 8 1 8	1	14
2		2 1 7 7 8 1 2	2 1 7 7 8 1 8	1	14
3		0 2 5 7 0 1 9	- 2 5 7 0 1 -	2	28
4		4 2 1 1 0 9 3	- 7 1 1 0 9 -	3	42
5		0 4 6 5 3 5 3	2 4 6 5 3 5 -	2	28
6		4 2 1 1 0 9 3	- 2 1 1 0 9 -	2	28
7		1 1 9 3 4 9 0	- 1 9 3 4 9 -	2	28
8		0 2 1 4 4 8 2	- 2 1 4 4 8 -	2	28
9		0 8 0 0 1 6 0	- 8 0 0 1 6 -	2	28
10		0 4 2 7 7 7 6	- 4 2 7 7 7 2	2	28
11		0 5 8 5 5 9 7	5 5 8 6 6 9 7	2	28
12		0 2 0 6 7 9 5	0 2 0 5 7 9 -	1	14
13		0 1 1 3 1 1 4	0 1 1 3 1 1 -	1	14
14		1 5 7 0 0 5 4	- 5 7 0 0 5 -	2	28
15		0 0 1 4 0 5 9	- 0 1 4 0 5 -	2	28
16		0 0 1 8 7 7 7	- 0 1 8 7 7 -	2	28
17		0 1 0 7 9 3 4	0 1 0 7 9 3 -	1	14
18		0 0 0 0 1 7 1	- 0 0 0 1 7 -	2	28
19		0 2 0 6 7 2 1	5 2 0 6 7 2 -	2	28
20		0 4 5 3 6 2 8	- 4 5 3 6 2 -	2	28
21		0 6 1 7 4 4 9	- 6 1 7 4 4 -	2	28
22		1 1 6 4 7 4 6	5 1 6 4 7 4-	2	28
23		0 1 0 0 4 5 2	0 1 0 0 4 5 -	1	14
24		0 1 7 2 8 7 -	1 1 7 2 8 7 -	1	14
25		0 7 9 0 5 8 4	- 7 9 0 5 8 -	2	28
26		0 1 4 4 5 7 0	0 1 4 4 5 4 -	2	28
			Average Error Ratio%		24,7

From the experimental results, the average error is 24.7%, and the accuracy of this test is 75.2%. This occurs overfitting the model because it has high training accuracy but cannot recognize the testing data of the new image model; it is possible that errors can be caused because the model cannot identify new data and the shooting is not good.

D. Conclusion

The application of making this application consists of three general stages, namely (1) Image Preprocessing, (2) Image Segmentation, (3) Digit Recognition using the neural network method; the image preprocessing and image segmentation stages make it easy for a digit recognition system to recognize water meter numbers, with various problems taking pictures of PDAM system water meter numbers can get an identification accuracy of around 75.2%.

This research is still far from perfect accuracy numbers, so suggestions for future research are expected to increase the accuracy value by improving the image preprocessing method and setting neural network parameters so that they can detect digit numbers accurately and precisely. Additionally, it is necessary to re-optimize each method within the water meter digit recognition system, particularly during the conversion of a photo image of a water meter into text.

E. Acknowledgement

We are grateful to PDAM Surya Sembada City of Surabaya for giving us permission to use the water meter photo data that has been collected as research material, the digit recognition system uses local projections depending on clustering

F. References

[1] Badan Standardisasi Nasional, “Spesifikasi meter air minum,” pp. 1–45, 2008.

[2] P. A. Air, "AETRA," PT. Aetra Air, 11 October 2016. [Online]. Available: http://www.aetra.co.id/sahabat_aetra/detail/15/meter-air-terawat-akuratcegah-tagihan-tinggi. [Accessed 18 December 2020].

[3] W. B. Indonesia, "Wikipedia Bahasa Indonesia," 8 April 2020. [Online]. Available: https://id.wikipedia.org/wiki/pdam. [Accessed 2020 December 2020].

[4] H. N. Do, M. T. Vo, B. Q. Vuong, H. T. Pham, A. H. Nguyen, and H. Q. Luong, “Automatic license plate recognition using mobile device,” *Int. Conf. Adv. Technol. Commun.*, pp. 268–271, 2016, doi: 10.1109/ATC.2016.7764786.

[5] N. Jawas and Indrianto, “Image based automatic water meter reader,” *J. Phys. Conf. Ser.*, vol. 953, no. 1, 2018, doi: 10.1088/1742-6596/953/1/012027.

[6] A. Mutholib, T. S. Gunawan, J. Chebil, and M. Kartiwi, “Optimization of ANPR algorithm on android mobile phone,” *2013 IEEE Int. Conf. Smart Instrumentation, Meas. Appl. ICSIMA 2013*, no. November, pp. 26–27, 2013, doi: 10.1109/ICSIMA.2013.6717950.

[7] L. A. Elrefaei, A. Bajaber, S. Natheir, N. Abusanab, and M. Bazi, “Automatic electricity meter reading based on image processing,” *2015 IEEE Jordan Conf. Appl. Electr. Eng. Comput. Technol. AEECT 2015*, pp. 4–8, 2015, doi: 10.1109/AEECT.2015.7360571.

[8] S. Jaiswal, A. Prajapati, N. Shirodkar, P. Tanawade, and P. C. Gala, “Electricity

Meter Reading Based on Image Processing," vol. 7, no. 4, pp. 11188–11190, 2017.
[9] A. Mutholib, T. S. Gunawan, and M. Kartiwi, "Design and implementation of automatic number plate recognition on Android platform," *2012 Int. Conf. Comput. Commun. Eng. ICCCE 2012*, no. July, pp. 540–543, 2012, doi: 10.1109/ICCCE.2012.6271245.
[10] J. Kotwal, S. Pawar, S. Pansare, M. Khopade, and P. Mahalunkar, "Android App for Meter Reading," vol. 4, no. 1, pp. 9853–9857, 2015.
[11] M. Shalini, M. Phil, and D. Ph, "Character Segmentation For Telugu Image Document," pp. 528–533.
[12] R. P. Dos Santos, G. S. Clemente, T. I. Ren, and G. D. C. Calvalcanti, "Text line segmentation based on morphology and histogram projection," *Proc. Int. Conf. Doc. Anal. Recognition, ICDAR*, pp. 651–655, 2009, doi: 10.1109/ICDAR.2009.183.
[13] J. A. Martín H, J. Montero, J. Yáñez, and D. Gómez, "A divisive hierarchical k-means based algorihtm for image segmentation," *Proc. 2010 IEEE Int. Conf. Intell. Syst. Knowl. Eng. ISKE 2010*, pp. 300–304, 2010, doi: 10.1109/ISKE.2010.5680865.
[14] Wikipedia, "Wikipedia," Wikipedia, 9 December 2020. [Online]. Available: https://en.wikipedia.org/wiki/Hierarchical_clustering. [Accessed 16 January 2021].
[15] Wikipedia ,"Wikipedia Indonesia," Wikipedia, 26 November 2020. [Online]. Available: https://id.wikipedia.org/wiki/Jaringan_saraf_tiruan. [Accessed 16 January 2021].
[16] A. Nodari and I. Gallo, "A multi-neural network approach to image detection and segmentation of gas meter counter," *Proc. 12th IAPR Conf. Mach. Vis. Appl. MVA 2011*, no. January 2015, pp. 239–242, 2011.
[17] M. Nejati, A. Majidi, and M. Jalalat, "License plate recognition based on edge histogram analysis and classifier ensemble," *2015 Signal Process. Intell. Syst. Conf. Sp. 2015*, no. December, pp. 48–52, 2016, doi: 10.1109/SPIS.2015.7422310.
[18] A. Saltelli *et al.*, *Sensitivity Analysis for Neural Networks. Natural Computing*, vol. 159, no. 2–3. 2009.
[19] S. Afroge, B. Ahmed, and F. Mahmud, "Optical Character Recognition using Back Propagation Neural Network," no. December, pp. 8–10, 2016.