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RESEARCH ARTICLE

Water Meter Reading Application System Development Using Image Processing: A Case Study from Sindangsari Village Water Services

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Abstract: PAMDES is a drinking water company managed by local villagers in Indonesia. The water meter data are read and recorded manually without any technology, which is ineffective and inefficient. Digital image processing can be implemented to read and record the water meter data automatically. When implemented in the water meter, it can help PAMDES officers to read the data without the internet, without changing the conventional water meter device, and the water meter data can be read and recorded effectively and efficiently. This research used the agile method, one of the methods used in the software development life cycle (SDLC). The method is done repetitively within a short period of time. The output of this research is an application with a digital image processing model that can read water meter data up to 82 % in normal conditions and still can be improved. This research aims to make the water meter data reading and recording more effective and efficient and to contribute to the transformation of Sindangsari village into a digitalized village.

Keywords: digital image processing, village digitalization, village water company, water meter recognition

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1 Introduction

Water is an important element in human life. People usually use clean water from rivers, lakes, springs, or drinking water companies for daily activities. The use of water from the drinking water company is usually measured using a water meter placed in every neighboring house. In Indonesia, PDAM (standing for Perusahaan Daerah Air Minum or Local Water Company) is a drinking water company in charge of drinking water on the scale of a town. Meanwhile, PAMDES (stands for Perusahaan Air Minum Desa or Water Village Company) is a drinking water company in charge of the scale of a village. The villagers manage PAMDES, and one example is PAMDES in Sindangsari village. Sindangsari village is located in Cikoneng, Ciamis district, West Java province. Sindangsari PAMDES holds an important role in distributing clean water to the people in Sindangsari village. Drinking water companies are not only focusing on profit but also their contribution to society. Drinking water companies can be rated by the quality of their service and work ethics. Giving the best service is one of the company's responsibilities. In this case, improving management and information delivery can enhance service quality. However, Sindangsari PAMDES management processes such as water meter data recording, administration, and customer information delivery are still done manually. Drinking water companies are encouraged to develop and implement technology to improve the management process and enhance the quality of service given to society [1].

To record water meter data, PAMDES officers usually do it manually by visiting the houses one by one. The officers need to record the monthly data to calculate each customer's water bill. The process is done manually because the water meter device used is still conventional. There are some researches related to the water meter data reading and monitoring using IoT-based microcontrollers [2,3] that aim to monitor water meter data in real-time using the internet. In those cases, the research relies on the internet connection, and the monitoring system will be unable to work correctly if the internet connection is unavailable or disconnected.

Other related research uses a smart meter in which each customer can determine how many liters they will use each month. If the use exceeds the limit, the smart meter will automatically close the valve on the water meter [4]. The other research was done for a different purpose, which is to detect water leakage using the ensemble outlier method. It detects water leakage by setting the threshold for every water meter, and the water meter with data anomaly usually has a leakage problem because it exceeds the predetermined limit [5]. Another research with a similar goal uses big data to create a detection system for water meter reading anomalies, such as conditions where the water meter is broken, water leakage, and so on. The detection system was done by reading the pattern of the water meter data of every customer for each month [6].

There is also another research for water meter data reading using a cellular device without an internet connection, but the research was for a digital water meter [7]. A 433 MHz wireless transceiver was used to convert the analog water meter data into digital [8]. Similar research used the ORB algorithm for water meter data reading to replace inspection robots [9]. Water meter data recording can also be done using the neural network [10,11]. Using the neural network, the data recording does not depend on the internet connection, and water meter data can be read without an internet connection. Another study aims for a different purpose which is to predict water production [12]. A study implements artificial intelligence using the backpropagation method [13].

This research uses digital image processing technology to read the water meter data. Many studies already implemented digital image processing, including the discovery of green patches in the desert [14], crack detection [15], and dynamic changes in multiple sclerosis lesions [16]. Material degradation assessment [17]. Measurement of coarse aggregate movement characteristics within asphalt mixture [18]. Evaluation of the evolution of the structure of cold recycled mixture subjected to wheel tracking [19]. Detecting plant Diseases, quantifying and classifying [20].

This research was done in Sindangsari village, Cikoneng, Ciamis district, West Java province. The conventional water meter device will not be a problem for data reading using digital image processing, and the data can be read fast without using an internet connection. The goal is to digitalize the water meter data reading and recording process.

2 Research Method

The Agile Development Method is a method used for software development. In the Agile Development Method, software development is done repetitively within a short period of time. The implemented Agile Development Method can be seen in Figure 1.

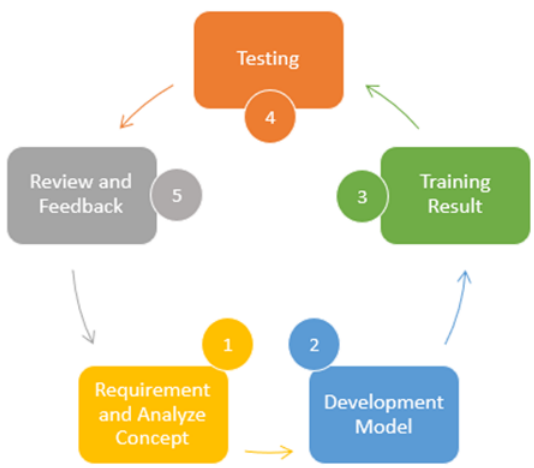


Figure 1: Agile development model.

The first step in this process is the Requirement and Analyze Concept. The data required to develop the model is collected in this step, and the application concept is analyzed. The data that needs to be collected is the data from the current condition. In this research, among the data to be collected is the sample picture of the water meter. PAMDES officers help to gather the data as well as analyze the application concept to make sure that the application meets the needed requirements.

The next step at this stage is the Development Model. This stage is a continuation of the previous stage, where at this stage, the development of applications and models for digital image processing is carried out. The development of a digital image processing model can be proceeded by using the necessary data. The development of a digital image processing model is carried out by conducting model training so that the model can recognize the image we want, namely the image of a water meter.

At this stage, a convolutional recurrent neural network (CRNN) is used to perform digit extraction. CRNN is a combination of convolutional neural network (CNN) and recurrent neural network (RNN). The advantages of a CNN can extract high-level features that are invariant to local temporal and spectral variations because the CNN includes convolution layers, activation functions, and also pooling layers [21]. Meanwhile, RNN is one of the most important neural networks and can be used for sequence feature extraction [22]. CRNN is a refinement of the previous model and has special advantages in similar object sequences because there is no length limit for class sequence objects [23]. This study uses CRNN because it is the most superior and uses many similar objects. The images used in this study are images of water meters and the water meters used are conventional water meters which are typical and specific in Sindangsari village and even in Indonesian country.

After the Model Development step, the next step is the third step at the stage, namely the Training Result. At this stage, the application is combined with a model that has been trained to recognize the image we want, namely the image of a water meter. The application can take a photo of the meter directly, and the image processing model can immediately recognize and perform analysis and reading on the image.

In the next stage, the Testing step is carried out. At this step, the application is almost finished. The purpose of this step is to ensure and double-check that there are no bugs in the application, all functions in the application are running properly, and the image reading on the digital image processing model is carried out accurately. For application testing, alpha testing is used, namely the Blackbox testing. In Blackbox testing, the testing process is carried out on every detail of the application features, trying to see the output issued by the application for every given input. Testing is said to be successful if the output that comes out on each feature of the application is as desired.

The next stage is the Review and Feedback stage. At this stage, a review is carried out on the results of the digital image processing model. This review activity shows how many images can be correctly detected by the digital image processing model used. From the results of the review, feedback was obtained in the form of a decision to repeat or not the creation of a digital image processing model for the application.

In this study, digit extraction will be performed using a CRNN. As illustrated in Figure 2, the digit extraction process with CRNN is divided into two stages, which utilize openCV and pytesseract. The first stage involves performing Canny edge detection to remove irrelevant objects from the image, converting the image to binary, and searching for contours. In the second stage, digits are detected using the ROI value based on the obtained contour, and a string of detected numbers is produced.

At the review and feedback stage, calculations are carried out to determine the success rate of detecting the water meter number using the model that has been created. Equation 1 is used to calculate the success rate.

$$S_r = \frac{TI_{true}}{TI_{testing}} \times 100 \tag{1}$$

To calculate the success rate S_r for each trial, the number of correctly identified images TI_{true} is divided by the total number of attempted images $TI_{testing}$ and multiplied by

```
image = cv2.imread("meter_1.jpg")
gray_image = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)

edges = cv2.Canny(gray_image, 400, 300, apertureSize=3)
image_ret = edges.copy()

ret, thresh = cv2.threshold(image_ret, 127, 255, 0)
contours, hierarchy = cv2.findContours(thresh, cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_NONE)
digits = dict()

for (i, c) in enumerate(contours):
  if cv2.contourArea(c) > 10000:
    (x, y, w, h) = cv2.boundingRect(c)
    roi = thresh[y:y + h, x:x + w]
    digits[i] = roi
    break

cv2.imshow(digits[i])

# just need the numbers
custom_config = r'--oem 3 --psm 7 outbase digits'
print(pytesseract.image_to_string(digits[i], config=custom_config))
```

Figure 2: Digit extraction code.

100 %. This success rate indicates the model's ability to accurately detect the water meter number and helps to evaluate its effectiveness.

3 Results

This research creates solutions based on predetermined research methods. The results obtained are in the form of a digital image processing model that can read the water meter numbers.

Figure 3 explains that by inputting the desired raw image, the image will be fed to the network in the first stage layer, namely CNN. In the next stage, the CNN divides the image into feature columns which will then become feature maps, commonly called convolutional feature maps. The convolutional feature maps will then be sorted into feature sequences or also known as feature sequences, which will be included in the bidirectional LSTM sequence. The neural network handles issuing sequences and finding relationships between characters or text. After the sequence has been issued, the result will consist of several characters, and after passing through the transcript stage through a probabilistic method, characters will appear in the form of text that has been properly sorted.

The model will be included in the application so the PAMDES officers can record water meters effectively and efficiently. Officers will be able to record just by taking a photo of the customer's water meter. After being photographed, the digital image processing model will take a reading of the water meter, and the reading results will immediately appear in the This Month Value column, which indicates the customer's water meter reading results this month.

Figure 4 is the application display PAMDES officers will use to read customer water meter data. Officers can first check customer data before taking water meter readings. The

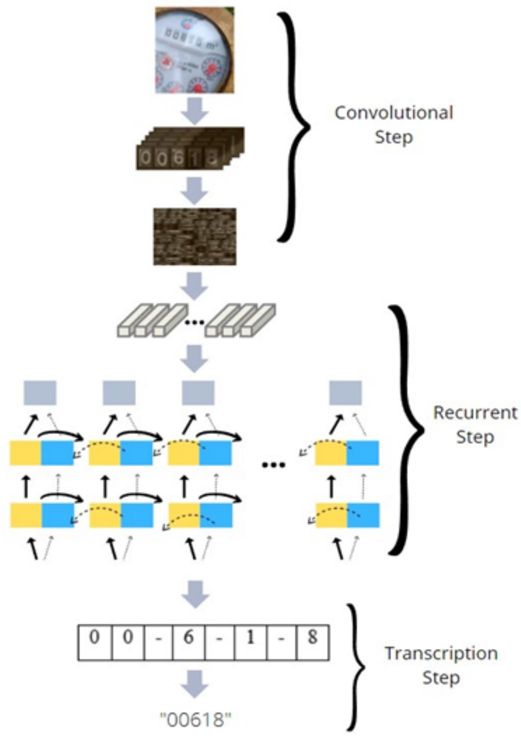


Figure 3: Digit extraction.

officers can see the customer's name on the first line and the customer's address on the second line. Officers can re-check customer connection numbers before the data reading process begin, and officers can also find out the customer's meter data for the previous month. Afterward, the current meter data will be filled automatically after the officer has taken a photo of the customer's water meter because right after the digital image processing process is complete, the model will automatically read the data.

4 Discussion

The digital image processing model has been through several trainings to recognize images of customers water meters. Before the model was implemented, an experiment was carried out to see how accurate the digital image processing model was in reading the customer's water meter. From the experiment, an evaluation can also be obtained to improve the accuracy of the digital image processing model when reading the customer's water meter. The following are the results of the digital image processing model experiments that have been trained beforehand.

The test results came out in .csv format as shown in Figure 5, and the accuracy for the trained model was 82 %. For the incorrectly read images during the testing process, the review and feedback step was done to evaluate the testing process. Several factors

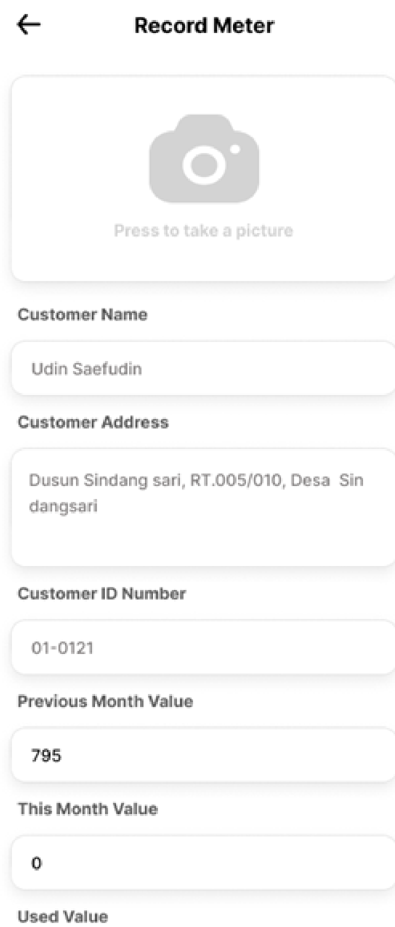


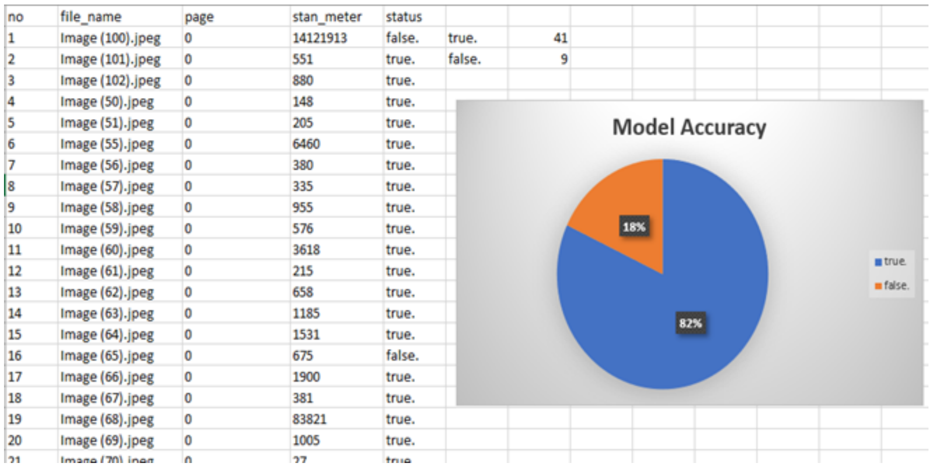
Figure 4: Water meter reading application display.

were found that caused the digital image processing model to fail to read the water meter perfectly.

In Figure 6, the performance success rate from the results of digital image processing model testing is 82 % of 50 sample water meter images, or the same as 41 water meter images. At the same time, the water meter that failed to read was 18 % of the 50 sample water meter images or the same as nine water meter images.

Do as many as five iterations with the same model and image. Each iteration is tested on the same 50 images, and the model used is also the same model without additional model training. This test is carried out to see how consistent the water meter readings of the model that have been trained are. Following are the test results of the five iterations:

The iteration results can be seen in Table 1, the results of the first iteration obtained 41 images successfully read, then the results of the second iteration obtained 40 images



no	file_name	page	stan_meter	status		
1	Image (100).jpeg	0	14121913	false.	true.	41
2	Image (101).jpeg	0	551	true.	false.	9
3	Image (102).jpeg	0	880	true.		
4	Image (50).jpeg	0	148	true.		
5	Image (51).jpeg	0	205	true.		
6	Image (55).jpeg	0	6460	true.		
7	Image (56).jpeg	0	380	true.		
8	Image (57).jpeg	0	335	true.		
9	Image (58).jpeg	0	955	true.		
10	Image (59).jpeg	0	576	true.		
11	Image (60).jpeg	0	3618	true.		
12	Image (61).jpeg	0	215	true.		
13	Image (62).jpeg	0	658	true.		
14	Image (63).jpeg	0	1185	true.		
15	Image (64).jpeg	0	1531	true.		
16	Image (65).jpeg	0	675	false.		
17	Image (66).jpeg	0	1900	true.		
18	Image (67).jpeg	0	381	true.		
19	Image (68).jpeg	0	83821	true.		
20	Image (69).jpeg	0	1005	true.		

Figure 5: Testing process model digital image processing.

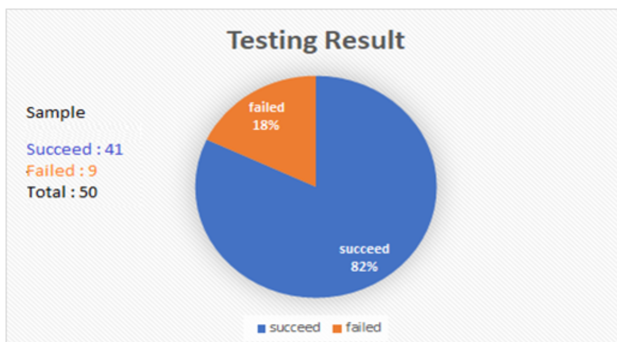


Figure 6: Digital image processing testing result.

successfully read, in the third iteration obtained 42 images successfully read, while in the fourth and fifth iterations 41 images were successfully read.

The results of the five iterations that have been carried out show quite consistent results. This is based on the average value of the number of images that have been successfully read in the model that has been made, namely 41 images or 82 %. From these results, there were

Table 1: Iteration result

Iteration	**Result**	
	Total Image successfully Read	**Success Rate**
1.	41	82%
2.	40	80%
3.	42	84%
4.	41	82%
5.	41	82%

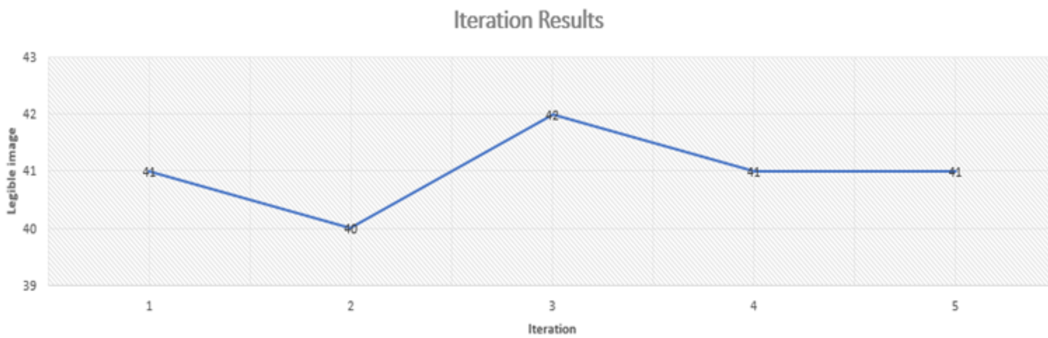


Figure 7: Iteration result graph.

no significant changes, the standard deviation of the iteration was also only 0.7071 which was relatively small and there were no readings with extreme changes from each iteration.

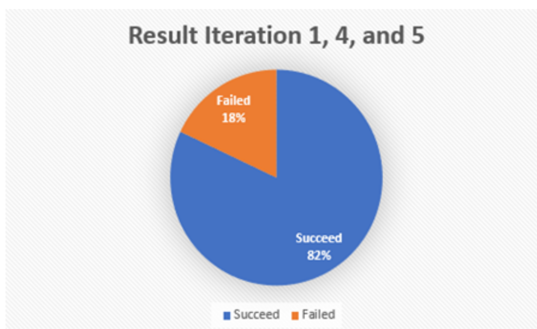


Figure 8: Iteration 1, 4, and 5 result graph.

In iterations 1, 4, and 5, the results were the same, namely 41 images were read successfully, and nine images failed to be read out of a total of 50 images (see Figure 8). In these three iterations, not only are the reading results the same, but the images that are successfully read and the images that fail to be read by the model that has been made are the same images.

In iteration 2, the result was 40 images were successfully read and 10 images failed to be read out of a total of 50 images (see Figure 9). In iteration 2 the image that failed to be read increased by one from the results of iteration 1, the failure to read occurred because the last digit on the water meter was not fully displayed so the model had to estimate the number in the last digit on the water meter.

In iteration 3, the result was 42 images were successfully read and eight images failed to be read out of a total of 50 images (see Figure 10). In iteration 3, one image was added that was successfully read from iteration 1, and an image that failed to be read in iteration 2 was successfully read in iteration 3. The reading was successful because the last digit was read properly, whereas in iterations 1 and 2, the last digit failed to be read. This is also because the last digit of the water meter is not fully displayed.

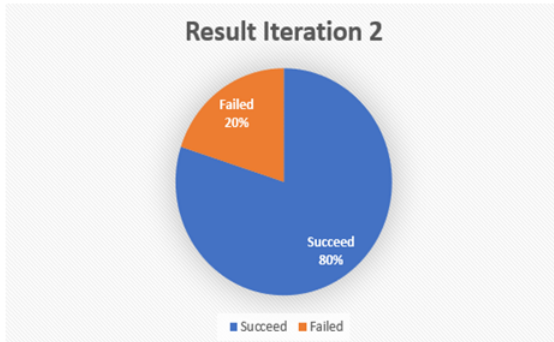


Figure 9: Iteration two result graph.

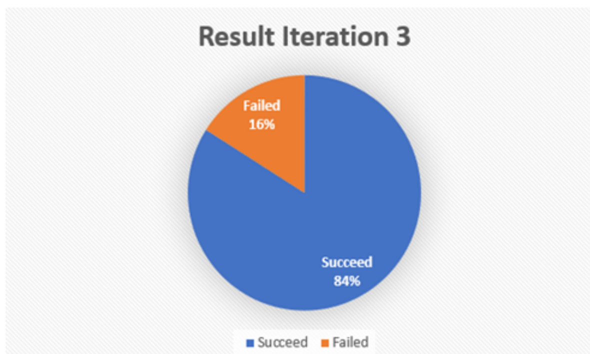


Figure 10: Iteration three result graph.

There are factors that result in the reading of the water meter numbers not being optimal, apart from the factor of the digital image processing model that has been trained, other factors such as the quality of the images taken at low resolution, the condition of the water meter which is blurry, and a different type of water meter. This affects the reading of the water meter. The first time you take an image plays an important role in influencing image reading, in this study the image was taken in ideal conditions so the possibility of successful image reading will be greater.

In Figure 11 is an example of a photo of a water meter that has been successfully read properly by a digital image processing model that has been trained. As can be seen in Figure 11, the numbers on the water meter are clear, the picture is not blurry, and the numbers on the water meter are still in good condition. Thus, an image of a water meter that can be easily recognized by a digital image processing model that has been trained is like the image in Figure 11.

Figure 12 is an example of a photo of a water meter that failed or was incorrectly read by a trained digital image processing model. As can be seen in Figure 12, the numbers on the water meter are not clear, the picture looks blurry, and the numbers on the water meter are covered with something. So the water meter image will be wrong when it is read by

Figure 11: Examples of water meter that reads well.

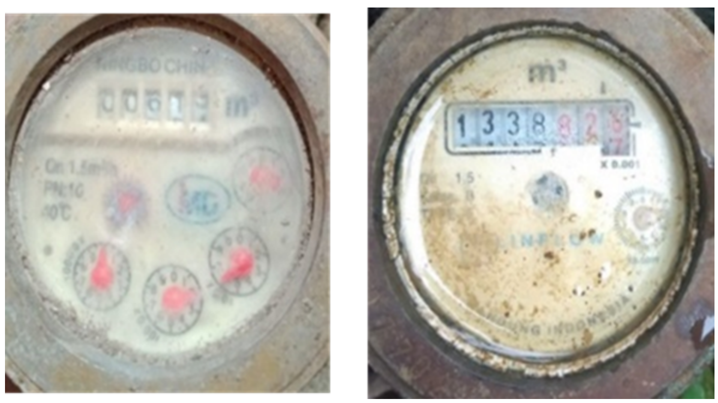


Figure 12: Examples of water meter that reads incorrectly.

a digital image processing model that has been trained with images such as the image in Figure 12.

5 Conclusion

It can be concluded that digital image processing can be used to change water meter readings to be more effective and efficient. Only by taking a photo of the customer's water meter, the PAMDES officers can immediately get the data of the water meter without having to write them manually. This can also encourage the management of an organization in the village to transform. Digital image processing models can also be continuously trained so that they can recognize water meters even better. The percentage of successful water meter readings by the digital image processing model is 82 % under normal conditions. However, PAMDES officers can also increase the success rate of the digital image processing model in reading the water meter by removing things blocking the meter glass so the camera can better capture the numbers on the meter. This technology can be continuously improved over time. Other problems in this area can also be solved with technology. Apart from solving problems with technology, Sindangsari village can also slowly develop into a digitalized village.

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