

## Digitization of Analogue Meter Reading Using Convolution Neural Network

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**ABSTRACT** – Analogue meter is a device that has been widely used in a various industry to monitor and obtain the reading of the measurement. Based on the conventional approach, the meter reading will be done continuously by the meter reader that might cause high tendency of human error during the observation. To minimize this fallacy, this approach taken in this paper enables the automation of this the process by obtaining the reading from an analogue meter using an image processing technique and send the output to the central database for further processing. By implementing this approach, observation efficacy can be improved. This paper describes the process on how to obtain the digitized reading of an analogue meter using images captured by a camera. The images are then processed using an image processing method and the Convolutional Neural Network (CNN) is used to determine the reading of the meter. Data is then sent to the MySQL database, as this approach was easily implemented and managed either on-premises or via the cloud. The use case in this study was based on the analogue meter for domestic electricity supply in Malaysia and results show that the meter reading can accurately be recognized using the proposed approach.

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## INTRODUCTION

Analogue meters such as electrical meter, water meter and gas meter are widely used in many industries due to its robustness. In residential or commercial premises, analogue meter based on electromechanical meter are commonly installed and the information on the electricity consumption unit is collected manually every month. However, this conventional approach has the following downside, for instance, meter readers must be hired and they need to move from premise to to premise to record the data and communicate with a receiving module [1]. Based on this conventional approach, the use of manual meters to translate the meter reading are prone to human mistakes.

To overcome this limitation, there are few prevention method that can be implemented to solve this issue. One of it is by using the Computer Vision (CV) approach. This is done by locating the area of the meter that contain the measurement information and extracting the information without any human intervention. It consists of a combinations of processes including digital image processing, pattern recognition, Artificial Intelligence (AI) and computer graphics [2]. Image processing itself has brought benefits in different areas of technology especially to analyze the image to obtain necessary informations.

To increase the efficiency of the data collection process, the data can be transferred to a central database for further processing and analytics where instant analysis and decision making can be performed. For instance, in emergency cases such as occurrences of short circuits in buildings or factories that lead to fire need an instant analysis from the control room to control the situation. Therefore, this work aims to ensure the developed system is reliable to perform any mitigation process.

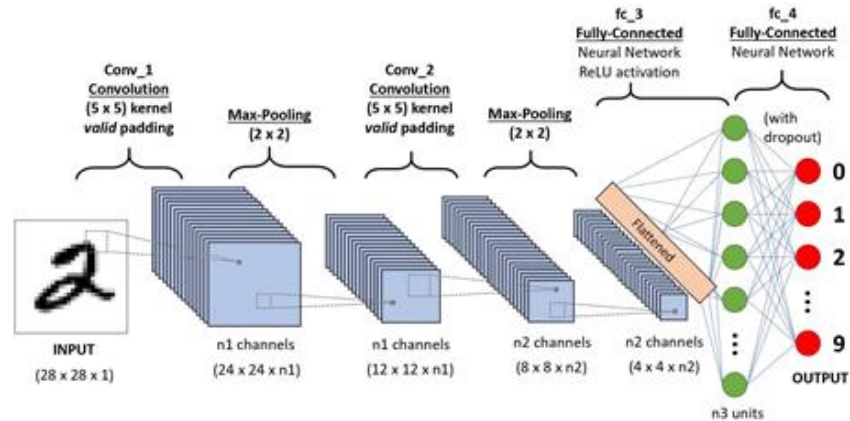
The use case in this study will focus on the analogue meter for domestic electricity supply in Malaysia. Throughout the development on this project, we assume that the surrounding brightness is optimum to capture the meter information images. The digits that will be analyzed are considered in decimal numbers and the recognized digit will be send to the database. The distance of the camera is set to 0.5 m from the analogue meter and both in static positions.

## LITERATURE REVIEW

### Convolution Nueral Network

Convolutional Neural Network (CNN) consist of a deep learning algorithm that takes the input images and extracts the image features by performing a convolutional process using filters such as kernels [3]. Compared to the traditional algorithms, this approach is able to produce better performance [4]. CNN is commonly used in data analysis or classification problems. Generally, it is used to detect patterns from images that make it extremely useful for image analysis. It is composed of a hidden layer called a convolutional layer, and an input layer to feed the image and finally

perform prediction on the images from the output layer. According to Kolmogorov, a 3-layer artificial neural network can approximate any nonlinear continuous function [5]. This process is called as a convolution operation. To perform the convolutional process,  $M \times M$  image is convolved with a filter of size  $f \times f$  across the entire pixel of the image. For instance, if the size of the filter is  $3 \times 3$ , with the image size (width x height) of  $45 \times 45$ , low level and high level features such as line, shape to identify pattern from the image will be extracted [6].



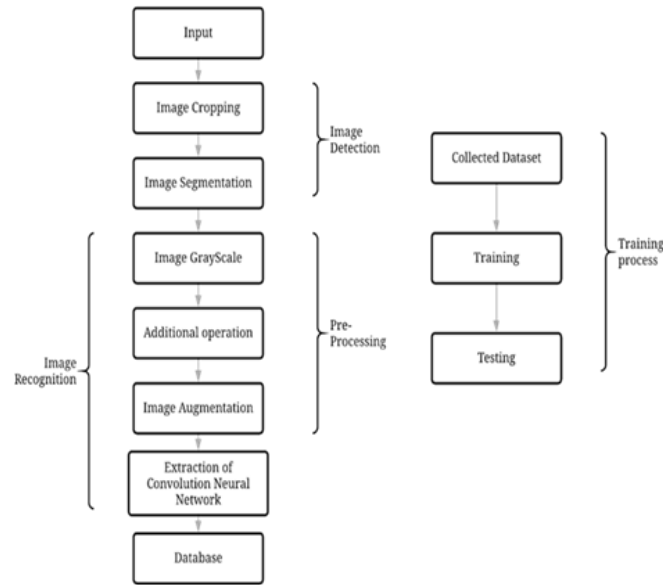
**Figure 1.** Architecture of CNN proposed

## Morphology

Morphology is a tool to extract importance components of an image such as boundaries and skeleton. There are a few types of morphology operations available in the literatures such as dilation, erosion, closing, and opening. Dilation is the same process as convolution that convolve with image A and structuring element B [7]. There are a few types of element A, like a triangular, diamond, square, ring, circular disk, and octagonal [8]. The operation of dilation occurred if any object at element A intercepts with element B. The size of the output image becomes expanded after the dilation. The convolution process for erosion is as same as that of the dilation. However, the operation for erosion is slightly different from dilation. If any object as element A intercepts with element B, the intercept part from the object is eliminated. In this work, erosion is used in the morphological characters before the image is fed into the CNN process.

## METHODOLOGY

The main objective of this project is to build and enhance the analogue meter recognition system. The main process in the model development of the system is divided into two parts, which are (1) image detection and (2) image recognition, as illustrated in Figure 2. For image detection, image cropping and segmentation were applied to the region of interest. Next, to increase model generalization, image augmentation was implemented on the detected images and unintended images (images with noise) were removed in the pre-processing stage. To enhance the accuracy of the model, a few image processing methods were applied. For recognition phase, the characters (numbers) were identified from the analogue meter. Finally, extracted information was saved and sent to the database for the data management purpose.



**Figure 2.** The proposed system

### Image Detection

Since the camera and the meter are considered to be static and the coordination of both devices will be in the same location through the process, the image detection can be done continuously for the same horizontal location of the digit area. As shown in Figure 3, each of the digits in the display will be cropped and passed for the next process, which is the segmentation process. The digits in the black frame of the digital region need to be segmented in order to recognize the next digits [9]. There are 7 parts from left to right in the rectangular frame of the digital area including 6 digits and a narrow scale division area for each part in a horizontal line. Next, character recognition is applied on the frame to isolate each number from the region.



**Figure 3.** Scanning of Segmented Cropped Image.

### Pre-processing

In pre-processing stage, there are four steps involved, which are:

#### i. Image Grayscale

Grayscale discards unnecessary information such as colors and saturation, which are not required for processing. An example of the output image obtained from this process is shown in Figure 4(b).

#### ii. Image Binarization

This step involves transferring an image to a black and white image. It is a fundamental step before reading the area of detection. In this step a threshold function needs to be defined.

#### iii. Erosion and Dilation

Erosion and dilation are used to make the character clearer for reading by adding and removing pixels on the image boundaries, and the output image after binarization, erosion and dilation processes is as shown in Figure 4(c).

#### iv. Median filtering

Since the salt and pepper noise type could appear on the image after the binarization, noise reduction algorithm must be applied to reduce the noises on the image. The result is as shown in Figure 4(d).



**Figure 4.** Preprocessing of (a) Original Image, (b) Grayscale Image, (c) Binarized, Erosion and Dilation Image, (d) Median Filtered Image

### Image Recognition

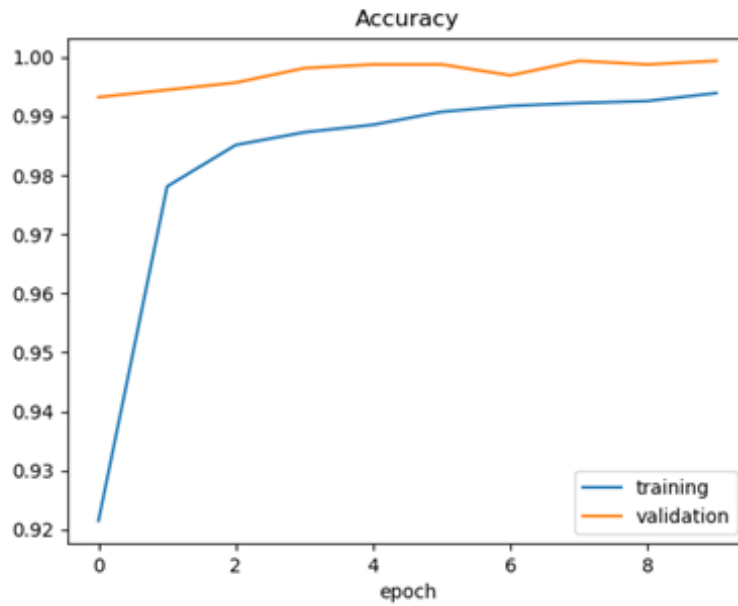
The datasets are divided into two parts, which are for training sample and validation sample. More than 10000 images for every digit from 0 to 9 with different resolutions of pixels have been used in this study. All the image including various font of digits are in JPG format. The image are distributed into separated class (folder) according to their digits value from 0 to 9. To begin with the model training, 80% of the samples were shuffled randomly for training sample, meanwhile another 20% were used as testing sample. To remove unintended noises and produce clean and sharp image for feature extraction, image pre-processing was applied on the image before beginning the training process. Model generalization is important in the training process, therefore data augmentation type such as zooming to focus on the intended areas and rotation to get better angle for images were applied in the model pipeline. The image size is set to 32 x 32 pixels.

In the model training process, backpropagation algorithm was used to calculate the gradient of the loss function with respect to the weights in all layers. Therefore, the weights and bias value were iteratively updated. The loss function was measured by taking the difference between the predicted output and the actual output for each training sample. Learning rate was used to ensure the convergence in the training process, and learning rate of 1.0 was used in this work. The total number of epoch to train the model was set to 20 epochs. To ensure that the model is well generalized, the accuracy and loss of the performance were monitored using a set of validation samples. Early stopping was introduced to avoid overfitting during model training.

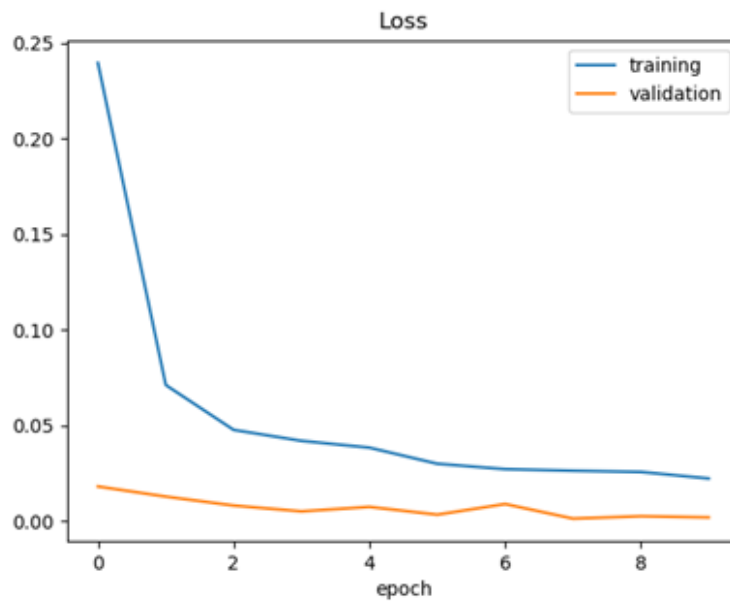
## RESULTS AND DISCUSSION

### Result on the Learning Process

The classification performance on the training sample was used to calculate the training loss, while the validation sample was used in calculating the validation loss. The validation loss is used as an indicator for early stopping. To illustrate this, Figure 5 and Figure 6 represent the training and validation performance for accuracy and loss, respectively. It shows as the number of epochs increase gradually, the loss performance in the training process start to converge over epoch. By looking at this graph, validation sample able to generalize pattern in the training sample. No overfitting was found in early 8 epoch of training. The model able to generalized with the accuracy approximately around ~99%.



**Figure 5.** Training and Validation Accuracy.



**Figure 6.** Training and Validation Loss.

### Database Collection

The recognized digits predicted from the CNN model were then sent to a MySQL database for further processing and analysis. Figure 7 illustrates the samples of the output that has been stored in a table located at the MySQL database. It shows the output results from the analogue meter, where the columns for the first digit to the sixth digit representing the meter reading read from left to right. The column labelled 'photo' shows the original image of the analogue meter. It is used for a validation purpose to identify any error from the input. The last column ('Regdate') indicate the registered date and time when the data is stored in the database.

	id	digit1	digit2	digit3	digit4	digit5	digit6	photo	Regdate
▶	1	7	7	5	3	4	0	BLOB	2021-06-11 22:27:09

**Figure 7.** Example of output in MySQL database

### Results of the System Performance

Table 1 shows the performance of the image recognition system 15 images, where out of the 15 images, 13 have been correctly recognized. 57 individual digits were successfully segmented from the 15 images with the accuracy rate of 86.67% and average probability of 0.837. To detect the cause of error during the process, all segmented digit are used to compare with the ground truth digit.

From Table 2., 49 out of 57 segmented digits were correctly recognized giving the accuracy of the performance with 85.96% and the average probability of true is 0.881. The unrecognized digits happened due to incomplete shape of the digit during the rotation process from one digit to another. Other than that, it is due to unclear image of digit from dusted or scratched glass cover on the analogue meter.

**Table 1.** Performance of the system (meter images)

Total number of analogue meter images	Correct reading recognition	Average Probability of true (Accuracy)
15	13 (86.67%)	0.837 (83.7%)

**Table 2.** Performance of the system (segmented images)

Total number of input segmented digit images	Correct individual digit segmentation	Average Probability of true (Accuracy)
57	49 (85.96%)	0.881 (88.1%)

### CONCLUSION

This paper presented a use case of analogue electricity meter reading system using an image processing technique. From the results discussion, it shows that the system is able to recognize the electric meter reading digits in three main phases of image processing with sufficient accuracy of 85.96% for each digit and the percentage accuracy of entire reading is 86.67%. This work also has introduced the noise filtering and image quality enhancement to improve the model efficiency. The extracted digits have been uploaded to MySQL database for recording purpose.

Another improvement can be made in this project is to reflect the solution with real-world situation. For example, different type of weather and brightness during data collection can be introduced in the future works. Meanwhile, from the side of database, it is good to introduce flexibility to the user to access the extracted information via mobile phone or smart devices.

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