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Rain detection in image using convolutional neural network

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Abstract. Weather is a phenomenon occurs in the earth's atmosphere. Weather affects human daily activities, especially outdoor activities. Weather observations including rainfall observation in Indonesia conducted by Meteorology, Climatology, and Geophysical Agency (BMKG). BMKG facing a major problem in terms of rainfall data spatial density. The insufficient amount and unevenly distributed rainfall measurement instrument, are two main factors contributing to rainfall data special density problems. One of the very prominent methods to gain a larger amount of rainfall measurement location is using the image obtained from existing Closed Circuit Television (CCTV) spread over vast areas, especially in the Jakarta region. The approach to recognize and classify the rainfall in a certain area from the CCTV image used in this research is the Convolutional Neural Network (CNN) method. The image data was taken from CCTV located in Kamal, Kalideres, West Jakarta. The images taken is split into two categories, the one that shows a rainy day and the one that shows a clear day. These two categories of images will be used as sample data to train CNN, an effort to obtain a suitable model. By using the CNN method, it's possible to recognize and classify the rainfall condition within an image based on the model. Python is an open-source programming language that widely used nowadays to run CNN. The image classification using this CNN, scored approximately 98.30% of accuracy, which means that the model is optimal to recognize and classify rainfall conditions in a certain area based on the CCTV images.

1. Introduction

The climate of Indonesia is almost entirely tropical. Being a tropical country, Indonesia is blessed with two seasons, namely dry and rainy. Weather is the state of the atmosphere at a particular place during a short period. Weather affects human daily activities, especially outdoor activities. Rain conditions that occur will affect human mobility, whether walking or using vehicles. Rain information in each region is needed to support various fields including transportation, economy, sport, and many other fields.

Meteorology, Climatology, and Geophysical Agency (BMKG) is an Indonesian non-departmental government agency that has the duty to conduct weather observations and provide weather information to the people of Indonesia. The needs for weather information are increasingly high. BMKG is demanded to provide weather information with locations that are getting tighter.

Rainfall is defined as liquid condensation of water vapor falling from clouds or deposited from the air onto the ground. Instruments for measuring rainfall include ordinary rain gauges, siphon rain gauges, and tipping bucket rain gauges. BMKG facing a major problem in terms of rainfall data spatial density. The insufficient amount and unevenly distributed rainfall measurement instrument, are two main factors contributing to rainfall data special density problems. One of the very prominent methods to gain a larger



amount of rainfall measurement location is using the image obtained from existing Closed Circuit Television (CCTV) spread over vast areas, especially in the Jakarta region.

The visual effects of rain are complex. Rain consists of spatially distributed drops falling at high velocities. Each drop refracts and reflects the environment, producing sharp intensity changes in an image [3].

One of the most popular techniques used for image classification is Convolutional Neural Networks (CNN). In this paper, we apply CNN to the recognition and detection of rainfall from the image and evaluate its performance. Our contributions are as follows: we built a dataset for rainfall detection experiments by using CCTV image located in Kamal, Kalideres, West Jakarta, we optimized CNN's parameters, through observation of our trained CNN, we found that color features dominate the rainfall recognition process, we showed that CNN has better performance for the task.

2. Research Methodology

In this subsection, the research methodology for this paper is presented below. The main goal of these research to classify and detect the rainfall on the CCTV image.

2.1. Convolutional Neural Network

Convolutional Neural Network is a Deep Learning algorithm. The structure of CNN is input, feature extraction, classification, and output. Figure 1 shows the convolutional neural network architecture.

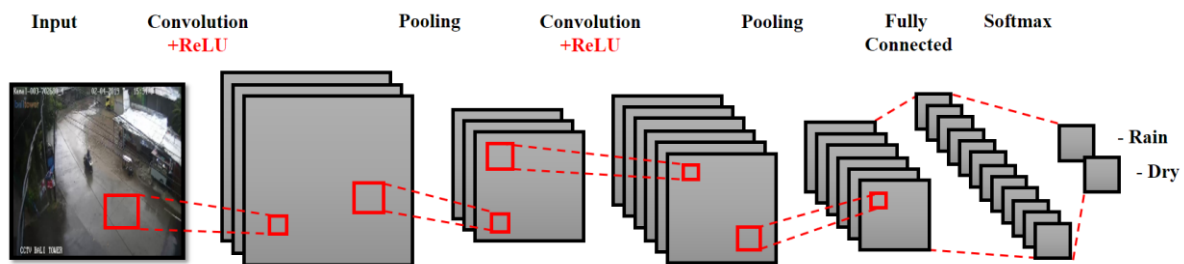


Figure 1. Convolutional neural network architecture

The CNN architecture for this research contains few layers and parameters which is described more detail below:

- **Input layer:** The input layer is a digital image data that will be used for the training and testing process. The input layer has a size in pixels. The Input layer has height, width and depth components. In this study, the input layer which has a large size will be resized to be smaller to speed up the processing time.
- **Convolution Layers:** The convolution layer is a major part of the CNN architecture. This layer uses filters that contain weights to detect characters from objects such as colors, curves or edges. On CNN the convolution will apply a kernel that moves from top left to bottom right to extract the input image.
- **Activation Layer (ReLU):** ReLU (Rectification Linear Unit) has a function to change the output value to 0 if the input is negative. If the input value is positive then the output value is the same as the activation input value itself. The ReLU activation function is $f(x) = \max(0, x)$.
- **Max Pooling:** this layer aims to reduce the size of an image by making the grid match the specified matrix size and taking the maximum value from the grid.
- **Fully Connected Layer:** this layer gets input from the previous process to determine which features are most correlated with a particular class. The function of this layer is to unite all nodes into one dimension [1].
- **Softmax:** softmax is used to get the classification results. The softmax function will calculate the probability of the results of the classification of the given input.

2.2. Methodology

The study uses digital images from CCTV located in Kamal, Kalideres, West Jakarta. Data is taken from the internet that can be freely accessed by the public. The data will then be processed using the Convolutional Neural Network method so that it can detect rain or dry conditions that occur at the location where the CCTV is installed. The stages of this study began with the collection of data used for input training, validation, and testing. The next step is to make a CNN network structure for the classification of digital images.

2.2.1. Data Collection. Data collection in this paper using automatic web crawling. The URL of the image will be visited and will be downloaded automatically. The quality of the image already has a full HD resolution. The data collected was 2480 images. Due to the limitations of image data with rain criteria, the data used are 40 images for rain criteria and 40 images for dry criteria. CCTV data obtained from the internet has a video format (.mp4) so it needs to be converted into an image format (.jpg). Figure 2 shows rain and dry conditions on a CCTV image.



Figure 2. CCTV image (a) dry, (b) rain

2.2.2. Design of CNN Structure. After collecting data, the next CNN structure design will be carried out. CNN has two stages namely feature learning and classification. CCTV images used have a size of 1920 x 1080 pixels, it is necessary to change the size so that the next process is not too long. Figure 3 Flowchart of CNN Structure.

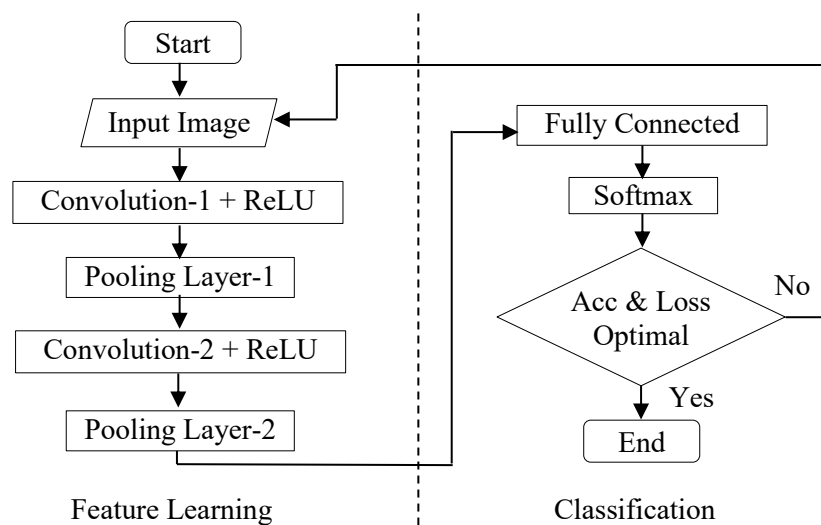


Figure 3. Flowchart of CNN structure

3. Experimental Result and Discussions

3.1. Training Process

The training process is a stage for obtaining CNN models with high accuracy. The data used for the training process are training data and validation data. The training data amounted to 50 images and validation data amounted to 20 images. Convolutional Neural Network has two stages, feature learning and classification. The designed CNN structure consists of two times the convolution layer and the two pooling layers. The next step is a fully connected layer process and the last is softmax activation to classify digital images based on the value of neurons in the hidden layer. To get high accuracy, five training processes are carried out with different parameter values. The results of the training process are shown in table 1 and figure 4.

Table 1. Training Accuracy

Epoch	Image size	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6	Accuracy	
1	5	150x150	Conv (32, 3x3) + ReLU	Max Pool (2x2)	Conv (64, 2x2) + ReLU	Max Pool (2x2)	Fully Connected	Softmax	82.68%
2	10	300x300	Conv (32, 3x3) + ReLU	Max Pool (2x2)	Conv (64, 2x2) + ReLU	Max Pool (2x2)	Fully Connected	Softmax	97.10%
3	15	600x600	Conv (64, 3x3) + ReLU	Max Pool (3x3)	Conv (64, 3x3) + ReLU	Max Pool (3x3)	Fully Connected	Softmax	97.05%
4	25	300x300	Conv (32, 2x2) + ReLU	Max Pool (3x3)	Conv (32, 2x2) + ReLU	Max Pool (3x3)	Fully Connected	Softmax	93.98%
5	50	150x150	Conv (32, 3x3) + ReLU	Max Pool (2x2)	Conv (64, 2x2) + ReLU	Max Pool (2x2)	Fully Connected	Softmax	98.30%

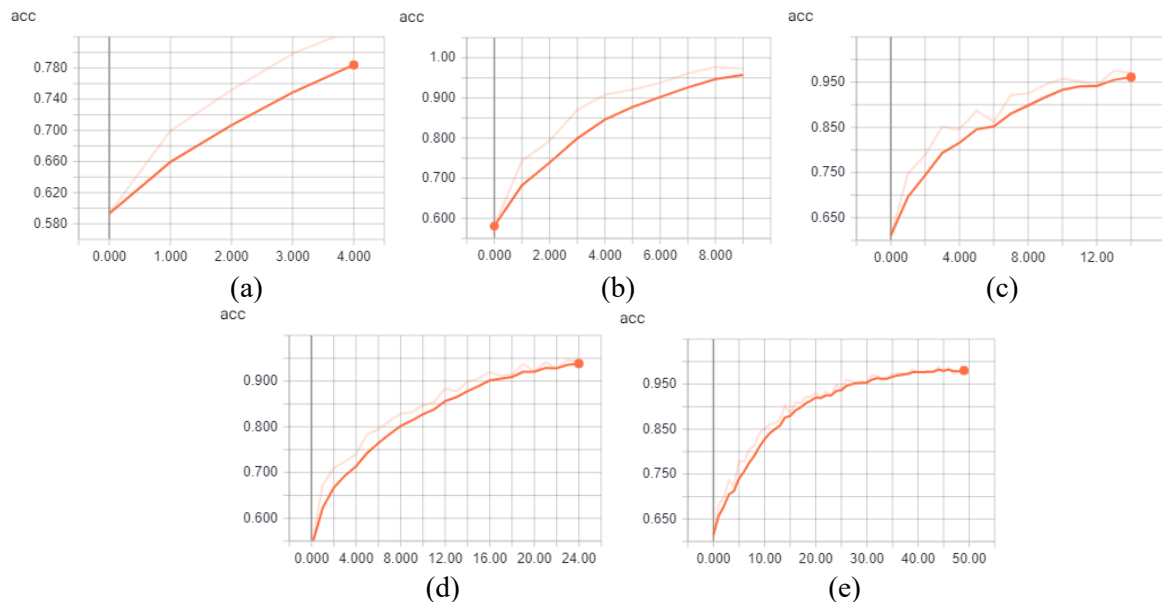


Figure 4. Training accuracy graph (a) Training-1, (b) Training-2, (c) Training-3, (d) Training-4, (e) Training-5

Five times the training process shows that the best accuracy is in the fifth training process with an accuracy of 98.30%. In the fifth training process the number of epochs is 50. The first convolution layer uses 32 filters and a 3x3 matrix size and is added with ReLU activation. Furthermore, Max Pooling is done with a 2x2 matrix. The third layer uses a convolution layer with a 64 filter and 2x2 matrix size and ReLU is added. The fourth layer uses max pooling with a 2x2 matrix size. Then through the process of fully connected layer and the last process is softmax.

Five times the training process carried out already showed high accuracy. This shows that CNN can classify rain on digital images well. The number of epochs and digital image size does not significantly affect accuracy. The accuracy value is more affected by the convolution layer and pooling layer values.

3.2. Testing Process

The testing process is a classification process of testing data, amounting to 10 images. Testing data will be classified in the rain or dry category. The testing process is done using a model generated from the training process. Table 2 shows the results of rain classification on digital images.

Table 2. Rain Classification Results

Category	Results									
	Training 1		Training 2		Training 3		Training 4		Training 5	
	Rain	Dry	Rain	Dry	Rain	Dry	Rain	Dry	Rain	Dry
Rain	4	1	4	1	5	0	5	0	4	1
Dry	1	4	0	5	0	5	2	3	0	5

The results of the classification of digital images from testing data using a model that was made already showed good results. Five models were made used for the classification of 10 digital images. Rainfall digital image prediction data shows that 22 classified correctly and 3 incorrectly. Bright digital image data prediction shows as many as 22 classified correctly and 3 wrong. The accuracy calculation for the testing process is the correct data divided by the amount of data so that it shows an accuracy value of 88%.

4. Conclusions

The rainfall detection method on digital images using convolutional neural networks is quite reliable to use. The accuracy value obtained has the highest value of 98.30%. In the testing process, the accuracy of the model created against the testing data shows a value of 88%. Five models made with different parameters showed an accuracy of 82.68%, 97.10%, 97.05%, 93.98%, and 98.30%. This shows the classification using CCN is quite reliable against parameter changes. By using a lot of training data and good quality digital images will produce a good classification.

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