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Implementation of Deep Learning for Slump Optimization Based on Concrete Quality Using Convolutional Neural Network in PT. Selo Progo Sakti

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ABSTRACT

Deep Learning is part of the scientific field of Machine Learning and Machine Learning is part of Artificial *Intelligence* science. Deep Learning has extraordinary capabilities by using a hardware Graphical Processing Unit (GPU) so that the artificial requirement network can run faster than using a Personal Computer Unit (CPU). Especially in terms of object classification in images using existing methods in the Convolutional Neural Network (CNN). The method used in this research is Preprocessing and Processing of Input Data, Training Process in which CNN is trained to obtain high accuracy from the classification carried out and the Testing Process which is a classification process using weights and bias from the results of the training process. This type of research is a pre experimental design (pre experimental design). The results of the object image classification test with different levels of confusion in the Concrete database with the Mix Design K-125, K-150, K-250 and K-300 produce an average accuracy value. This is also relevant to measuring the failure rate of concrete or slump.

INTRODUCTION

Until now, concrete is still the main choice in making structures, because basically it has the advantage of being easy to get its constituent materials, having high compressive strength, easy maintenance and forming. This is shown from data released by the Indonesian Cement Association (ASI) which presents the development of domestic cement consumption which shows an increase every year from 2010 to 2017.

Cement sales in 2018 reached 75.2 million tons, up 8.6% compared to the previous year. A total of 69.51 million tons were sales in the domestic market and 5.7 million tons from the export market.

Concrete is a material that is widely used in the construction industry with various forms and levels of quality in accordance with the intended use. This material is widely used as a building element because it is easily formed and can be produced in the field by mixing some raw materials either manually or with more sophisticated equipment (Lasino, 2003). Compressive strength is a concrete property that must be fulfilled by every reinforced concrete structure and slump is a characteristic of fresh concrete that determines hopefully the concrete is worked on. Compressive strength determines

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how much concrete capacity is in holding structure loads, while the slump determines the ease of concrete to be poured into the mold and compacted so that the concrete gets the strength as planned. Visually, the mixture of fresh concrete has a different texture for each different compressive strength and slump. Low quality concrete has a rougher texture compared to high quality concrete as well as concrete with a higher slump. This shows that the determination of compressive strength and slump can be done through an information technology approach by referring to the analysis of image texture / image of a fresh concrete mixture. To get a good quality concrete there are several things that need to be considered in its manufacture, including the selection of materials and good workmanship, which includes mixing materials, stirring, transporting, casting, compaction and good maintenance as well as strict quality control (Lasino, 2003).

Slump is basically one of the simple ways to find out the workability of fresh concrete before it is received and applied in casting work. Good fresh concrete is fresh concrete that can be stirred, transported, poured, compacted, there is no tendency for segregation (gravel separation from mortar) or bleeding (separation of water and cement from mortar). This is because segregation and bleeding result in the obtained concrete will produce poor quality. Good concrete (hard concrete) is strong concrete, durable / durable, waterproof, resistant to wear, and slightly changes in volume (small shrinkage) (Tjokrodimuljo, K., 2007). Workability of fresh concrete is generally associated with the following requirements :

1) Homogeneity or flatness of mixed concrete mix (homogeneity)
2) Stickiness of cement paste (cohesiveness)
3) The ability of fresh concrete flow (flowability)
4) The ability of fresh concrete to maintain evenness and viscosity when moved by means of conveyance (mobility)
5) Indicates whether fresh concrete is still in a plastic condition (plasticity)

The majority of Batching Plant companies engaged in concrete production have the same method in terms of producing concrete as well as measuring the strength of concrete or slump that is strength from 10 MPa to 100 MPa and slump workability from 0 mm to 180 mm. The problem that often arises is maintaining the quality of concrete in accordance with the predetermined mix design and workability of the slump from the location of the factory where it is produced to the location where the concrete material is poured. PT. Handaru Wijaya Mulya is an example of a manufacturing / batching plant company engaged in concrete production located on Jalan Yogya Wates, Ds Dlaban RT 005 / RW 003, Ex. Sentolo Kec. Sentolo, Kulon Progo. The difficulty experienced by the company is that when producing concrete with a certain quality of concrete must maintain the size of the slump from the factory location to the destination location of the concrete is held where so far it is still done manually based on the estimated distance to the destination location. Even then, slump measurements must be made when the concrete material is at the destination location by taking concrete samples and using a cone measuring device filled with concrete material then removed from the cone and measured the collapse characteristics of the material from the size of the cone.

Based on the description in the background, the research problem formulation is:

1. How to effectively and efficiently determine slump measurements from plant and destination locations.
2. How to formulate a mix design to determine the quality of concrete by considering the distance from the plant location to the destination location so that slump size can be maintained as when the quality of the concrete is at the factory.
3. Based on the analysis of image textures on fresh concrete mixes, how to implement deep learning for slump optimization based on concrete quality using convolutional neural networks.

MATERIALS AND METHODS

Convolutional Neural Network (CNN), often referred to as Artificial Neural Network, is a machine learning method which is a derivative of Artificial Intelligence from the development of Multi Layer Perceptron (MLP) which is designed to process two-dimensional data. CNN is included in the type of Deep Neural Network because of its deep network level and is widely implemented in image data.

CNN was initially introduced to NeoCognitron by Kunihiko Fukushima, from the NHK Broadcasting Science Research Laboratories, Kinuta, Setagaya, Tokyo, Japan (K. Fukushima, 1980). The concept was continued and developed by Yann LeChun, of AT&T Bell Laboratories in Holmdel, New Jersey, USA. The CNN model called LeNet can be implemented by LeChun in number recognition and handwriting (Y. LeCun, 1990). In 2012, Alex Krizhevsky by implementing CNN succeeded in dominating the ImageNet Large Scale Visual Recognition Challenge 2012. This event proved that the CNN Method succeeded in outperforming other Machine Learning methods such as SVM in the case of object classification in images.

The working principle of CNN is to present each neuron in two dimensions.

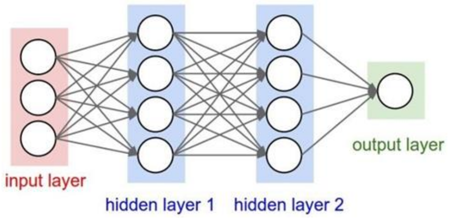

Figure. 1. Simple MLP Architecture

Figure 1 shows the i layer (red and blue boxes) containing ji neurons (white circles) on each layer. The input received by MLP will be propagated to produce output. Each relationship between neurons in two adjacent layers will have a one-dimensional weight parameter to determine the quality of the mode. The input layer data is performed linearly to obtain the weight value. The computational results are transformed using non-linear operations as an activation function.

Data propagation on the network consists of two-dimensional data, so that linear operations and weight parameters produce different outputs. Linear operation uses convolution, and weights are four-dimensional which are a collection of convolutional kernels as shown in Figure 2. The weight dimension is:

input neurons × output × height neurons × width

CNN can be used only on data that has a two-dimensional structure namely image and sound.

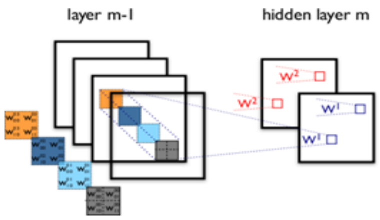

Figure.2. Convolution Process on CNN

Artificial Neural Network (ANN) is formed from several layers and several neurons on each layer. Neurons and layers cannot be determined using definite rules and apply differently using different data (D. Stathakis, 2008).

In the case of MLP, a network without a hidden layer can map any linear equation, while a network with one or two hidden layers can map most equations to simple data.

However, for more complex data, MLP has limitations. In the problem of the number of hidden layers under three layers, there is an approach to determine the number of neurons in each layer to approach optimal results. The use of layers above two is generally not recommended because it will cause overfitting and backpropagation strength to be significantly reduced.

To handle complex data, a function is needed to transform input data into simple data that is easily understood by MLP. This condition allows a model to be given several layers to transform the data before the data is processed using the classification method. This encourages the development of a neural network model with a layer number above three. Because the initial layer functions only as a feature extraction method, the number of layers in a DNN (Deep Neural Network) has no universal rules and varies depending on the dataset used.

A CNN consists of several layers. There are three main layers on a CNN, among others:

1) Convolution Layer

Convolution is a way to combine two series of numbers to produce a third series of numbers and so on repeatedly. With regard to object image processing, convolution means implementing a kernel (yellow box) on the image at all offsets as shown in Fig. 3. The green box is an image that will be completely convoluted. The movement of the Kernel starts from the top left corner to the bottom right and will produce a convolution of the image that is located in the image to the right.

Convolution in image data aims to extract features from the input image and will produce a linear transformation of the input data according to the spatial information in the data. The weight on the layer will specify the convolutional kernel which can then be trained based on the CNN input.

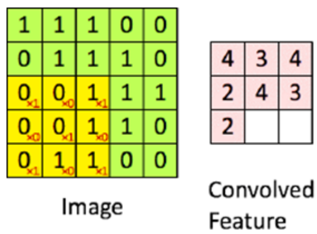

Figure.3. Convolved operation

2) Layer Subsampling

Subsampling is a process to reduce the size of an image object data. The purpose of subsampling is to increase the positional invariance of a feature. The subsampling method used in general is max pooling. The pooling layer usually comes after the convolution layer. In principle, the pooling layer consists of a filter with a certain size and stride that will shift the entire feature map area and will divide the output from the convolution layer into several small grids then take the maximum value from each grid to compile the image matrix as shown in Fig. 4 . The grid in red, green, yellow and blue is the group that has the maximum value and the results of this process can be seen on the right. Even though the image object has a translation (shift), the process will produce the same features.

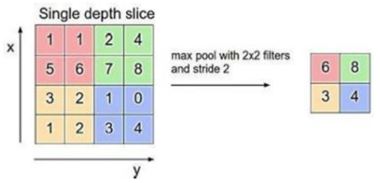

Figure.4. Max Pooling Operation

According to the opinion of Springenberg et al. (J. T. Springenberg, 2015), the use of pooling layer on CNN aims to reduce the image size so that it can be replaced by a convolution layer with the same stride and the pooling layer used.

3) Fully Connected Layer

The Fully Connected Layer is the layer used in the MLP implementation and aims to transform the data dimensions so that data can be classified linearly.

Before being put into a fully connected layer, each neuron in the convolution layer must be transformed into one-dimensional data first. The fully connected layer can only be implemented at the end of the network.

A convolution layer with a kernel size of 1 x 1 is capable of performing the same function as a fully connected layer provided that it maintains the spatial character of the data. Thus, this condition makes the use of the fully connected layer on CNN now not widely used.

Activation function is a function that exists in ANN to transform input data into higher dimensions so that it is possible to cut simple hyperlanes and can be classified. The activation function used in CNN is a sigmoid function.

The role of the sigmoid function is to transform the value range of the input x into a value between 0 and 1 with the form of the function distribution as shown in Fig. 5. The sigmoid function formula has a form as shown below:

$\sigma(x) = \quad 1$

$(1 + e{-}x)$

This causes the backpropagation process to occur which is not ideal, besides that the weights on ANN are not evenly distributed between positive and negative values and the weight values will mostly approach the extreme 0 or 1. Due to the computation of the propagation value using multiplication, this extreme value will cause the effect of saturating gradients where if the weight value is small enough, then over time the weight value will approach one of the extremes so that it has a gradient close to zero. If this happens, these neurons will not be able to undergo significant updates and will be disabled.

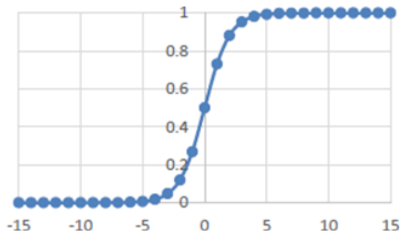

Figure.5. Distribution of Sigmoid Functions

This type of research is a pre-experimental design (pre experimental design) that is the researcher of the main group and intervene in it throughout the study (John W. Creswell, 2012). This design is said to be pre-experimental because it is not yet a genuine experiment due to the fact that there are still external variables that influence the formation of the dependent variable. This design is useful for obtaining preliminary information on questions in the study (Sugiyono, 2010). The design of one group pre-posttest design revealed a causal relationship by involving one group of subjects. Subject groups were observed before the intervention, then observed again after the intervention (Nursalam, 2008).

a. The implementation of deep learning includes the following process:

1) Pre-processing and Processing Data Input

An input image process will be processed into a pre-process that is the process of wrapping and cropping. In wrapping, the input image is checked against the edge of the main object in the image. From the edge of the image the maximum edge is determined so that when the results of cropping the object in the image remains intact.

2) Training Process

Training process is the stage where CNN is trained to obtain high accuracy from the classification conducted. This stage consists of the feed forward process and the backpropagation process.

3) Testing Process
Testing process is a classification process using weights and biases from the results of the training process. This process is not much different from the training process that distinguishes there is no backpropagation process after the feedforward process. So that the final results of this process produce accuracy from the classification performed, data that fails to be classified, image numbers that fail to be classified, and the shape of the network formed by the feedforward process.

b. Mix Design for each concrete quality
Low quality concrete has a rougher texture compared to high quality concrete as well as concrete with lower slump compared to concrete with higher slump. This variable is also influenced by the type of material imported from the supplier as a supplier of mix design material.

c. Variable controlled
The condition of the machine will affect the production process that supports the accuracy of the planned mix design.

d. Uncontrollable variable
The distance that is far enough will cause changes in concrete quality conditions, especially the size of the slump. Traffic congestion on the way to the location of the placement of concrete material also affects the stability of the slump size.

RESULTS AND DISCUSSION

The input image will be processed into a pre-process, namely the wrapping and cropping processes. In wrapping, the input image is checked against the edge of the main object in the image. From the edge of the image, the maximum edge is determined so that when the cropping result the object in the image remains intact. The training stage begins by converting the image into a vector form. The image data processing process starts with an image of any size which is then resized to 140 x 140. The image is made gray scale so that it can be processed easily at the training stage.

The training process is a stage where CNN is trained to obtain high accuracy from the classification carried out. This stage consists of the feed forward process and the backpropagation process. To start the feedforward process, the number and size of the layers to be formed, the size of the subsampling, and the obtained vector image are required

The testing process is a classification process using weights and bias from the results of the training process. This process is not much different from the training process which distinguishes there is no backpropagation process after the feedforward process. So that the final result of this process results in the accuracy of the classification performed, data that fails to be classified, the image number that fails to be classified, and the form of the network formed by the feedforward process.

Preprocessing methods and classification methods using Convolutional Neural Networks are reliable enough to determine the truth of the object image classification. This is proven by the accuracy of 20% - 50%.

The confusion level change does not affect the accuracy result. This proves that the classification using the CNN method is relatively reliable for the parameter changes made. By using good and optimal training data, the subset of the training data will also produce a good classification.

CONCLUSIONS AND SUGGESTIONS

The trial results of the developed methods and algorithms show that the measurement of texture characteristics globally in one image unit shows better results than the local measurement model. Global analysis on the contrast feature shows that the higher the compressive strength of the concrete, the smaller the contrast value which means the texture of the concrete image is getting smoother. Features energy can be used to distinguish slumps in concrete with compressive strengths K-125, K-150, K-250 and K-300. Feature correlation using erosion morphology with elemental structures less than 4 or features using dilation morphology with elemental structures more than 3 can be used to distinguish fresh concrete slumps. The KNN classification method is based on texture features.

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