Vehicles Potholes Detection Based Blob Detection Method and Neural Network Backpropagation Model

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Abstract

In Indonesia, especially on developing area, many potholes are occurred almost on every part of the road. The situation is exacerbated on how potholes location data gathering is performed manually by field personnel of the Department of Transportation or other related services, which would require more time and cost. This study aimed to produce a prototype of detection system and potholes location automatically. The prototype is a device attached on public transport so that it can be a solution for gathering potholes locations. Detection system with vision-based methods utilizes blob detection and neural network backpropagation. Blob detection is used to detect potholes based on convexity shape, while neural network backpropagation is used to detect potholes based on texture inside the potholes. The experiment of neural network using a segment grayscale value pattern that obtained from parts of a pothole with 25 x 25 in size. The prototype was built using Raspberry Pi and OpenCV library. Results shows quite low accuracy and still need to be improved.

Key words: Backpropagation, Blob Detection, Neural Network, Potholes, Raspberry Pi, OpenCV.

Introduction

According to the traffic Act No. 22 of 2009 article 229, paragraph 5 there are three factors that cause traffic accidents, namely the negligence of road users, unworthy vehicles, and also unworthy road. One of unworthy road is potholes. In 2014, from 95.906 the number of accidents recorded, there were at least 1.000 incidents or 18% was caused by the pothole. The situation is further exacerbated because until now the location point data of pothole is still done manually by field personnel or technician the Department of Transportation or related agencies of other highway maintenance, or still waiting for reports from people who certainly takes time and costs.

In computer vision, blob detection methods are aimed at detecting regions in a digital image that differ in properties, such as brightness or color, compared to surrounding regions. A Blob is a group of connected pixels in an image that share some common property. Object detection using blob detection method is to detect a flock of pixels that has different color (lighter or darker) than the background and integrate them into a region. The major advantage of object detection with the blob detection that was a simple process.

Artificial Neural Network is an information processing paradigm that is inspired by biological neural systems, like the brain that processes the information which consists of smallest processor units called neurons (Syafruddin et.at., 2012). Neural network was formed to solve a problem such as pattern recognition, classification, or detection due to the learning
process. Backpropagation is a supervised learning training techniques that are widely used because it is able to deal with the introduction of complex patterns. In backpropagation, each unit that is in the input layer is connected to every unit that is in the hidden layer.

Raspberry Pi is commonly abbreviated Raspi is a Single Board Computer that has a modest size (Halfacree & Upton, 2012). Raspberry Pi is an Linux-based open source so easily modified as needed. The main systems of Raspberry Pi using Debian GNU/Linux and Python programming languages. OpenCV, or Open Computer Vision is an open source library that is devoted to image processing based C/C++ is widely used in computer vision. OpenCV is designed for computational efficiency and provide the infrastructure of computer vision that is easy to use.

The purpose of this research is to produce a prototype of pothole detection attached on the public transport. If the prototype is successfully detects the presence of potholes, the system automatically records the location point of vehicle pothole with google maps API integration. The prototype was built with the Raspberry Pi and OpenCV aimed to producing a prototype that is cost-effective. Hopefully, the presence of prototype can facilitate the department of Transportation or the relevant office of highway maintenance to conduct location point data of pothole in creating conditions Zero Hole or Free Potholes on the road in Indonesia or in other places.

Related Work
As the visual form, potholes have the characteristics to distinguish it from other objects on the highway. In general, potholes has a circle-ellipse shape depending on the driver's viewpoint, is darker than the surrounding area, and the inner surface of the pothole is generally coarser than the surrounding road surface (Koch & Brilakis, 2011a).

Based on the physical form, the method used to detect pothole can be divided into vibration-based methods, 3D reconstruction-based methods, and vision-based methods (Taehyeong & Seung-Ki, 2014). 3D reconstruction-based methods are able to detect potholes until detects the volume of pothole, but it has a high cost to produce a system with this method (Koch & Brilakis, 2011a). Vibration-based methods can detect potholes without influenced by conditions surrounding it, but to be able to detect potholes, the system must first contact with potholes, which can certainly endanger the driver or the vehicle. In addition, the shock of speed bumps, bridge expansion joints, and sunken manhole can be detected as pothole (Eriksson et al., 2008). The use of other physical media such as InfraRed can also be undertaken, but not so effective on sunny day due to interference from sunlight (Nienaber et al., 2015).

Nienaber et al. (2015) using a simple image processing techniques to detect potholes. Image processing techniques are used such as canny filter and contour detection. The result has a precision of up to 81.8% but it still needs development in detecting pothole which its side clogged with dirt or sand. Pawade et.al. (2015) use Field Programmable Gate Arrays module to detect pothole. The system uses detection variation of Sobel, Prewitt and Canny edge. The results are able to provide the number of clear pothole, but has a relatively long process because the paralel algorithm process. Koch and Ioannis (2011a) classify the detection area based on the defect and non-defect. The use of shape-based thresholding algorithm histogram, morphological thinning, and elliptic regression are able to produce accuracy up to 85.9%, but has inefficient computing Koch and Brilakis (2011b).

Methods
Thresholding
Thresholding is the simplest method of image segmentation. Thresholding is used to segment an image by setting all pixels intensity whose values are above a threshold to a foreground value and all the remaining pixels to a background value. Thesholding process is undertaken to further process efficiencies.
**Blob Detection**

Blob detection parameter used is convexity parameter. This parameter is used for pothole is generally circular with a different shape from the viewpoint of the driver. In OpenCV, the higher of convexity parameter value, the higher of convexity form level that can be detected, whereas if the value of convexity parameter is lower, then blob detection can detect until concave shape. Examples of the different forms based on the convexity level can be seen in Figure 1. All of object being detected as a blob and have parameter values as the given value will be regarded as a pothole. Then, the output of blob detection is final selection by using Neural Network Backpropagation. Neural Network Backpropagation is used to classify output of blob detection by dividing the asphalt with potholes by grayscale degree pattern of the inside of pothole.

![Figure 1](blob_detection.png)

**Figure 1.** The differences of blob based on convexity level

**Preprocessing**

Image acquisition for training data through the cropping process in size 75 x 75 pixels and converted to grayscale image for later classified as training data for potholes and for asphalt. Cropping image will be training data by taking a grayscale value vertically, so that the cropping image will have 75-degree pattern of grayscale value 1 x 75 pixel. Thus, for a sample size of 75 x 75, there are 75 patterns that can be taken, where:

- Conventional segmentation matrix models 1 x 75 pixel.
- Horizontal conventional segmentation with one group of pixels horizontally
- Vertical conventional segmentation with 75 groups of pixels vertically

Preprocessing process is shown in Figure 2.

![Figure 2](preprocessing.png)

**Figure 2.** The acquisition process of training data for neural network backpropagation

**Neural Network Training**

The process of neural network using a Matlab 2014b application. For training data of cropping and trees areas will be saved in a file format .mat. In making the target data, will be loaded on the training data that has been stored previously to be a target value according to the class are:

- Target rated 1 for training data of potholes
- Target rated 0 for training data of asphalt

The process of neural network training to do as much as 20000 epoch. Epoch is one cycle of neural network training. Error is error level to be achieved in the system. The system will stop to do training process if the number of epoch has been reached or error value has been as expected. MSE (Mean Square Error) is the mean square error (error). The smaller of MSE, the better of obtained result.
Figure 3(a) shows when the epoch maximum has been reached or training has been completed. The length of training with 20000 epoch during 38:21 minutes to achieve performance at 0.0274. Figure 3 (b) shows chart the relationship of target with output. R is a linear gradient as results of linear regression. If the output of network is exactly equal to its target, then the gradient will be worth 1. The closer of data with Fit line, the closer of trained pattern. In this 20000 epoch, most of data is almost exactly with the data target, as shown by the farthest data from Fit line is not more than 0.2.

In Figure 4 (a), X-axis is the number of epochs and Y-axis is the root mean squared error (RMSE) of the training data set for each epoch. The closer of Train line with Goal line, then mistake during the training is closer to the target to be achieved. RMSE value used to be one of criteria for a learning system to stop learning. In addition RMSE values can also be used as a criterion for epoch for the system to stop learning. RMSE is an error rate of output value of the learning system to the pairs value of training data output, in other words RMSE is a difference occurs between the desired output with the actual output. Based on the graph, it appears that the greater number of epoch, then error will decrease. After reaching epoch 2000, a decrease in the error is smaller and constant before epoch 18000. Target desired error at epoch 20000 is still far from the desired target.

Figure 4. (a) Performance of neural network training process. (b) Testing results with training data
As seen in Figure 4 (b) most of training data segment pattern has approached target/output given, although there is still some small segment pattern that is far from the desired target. For target 1 (potholes), the highest segment pattern is 1.28 and the lowest is 0.58. As for the target of 0 (asphalt), the highest segment pattern is 0.43 and the lowest is -0.38.

**Prototype System**

Raspberry Pi is used as the main device and the main processor of resulted prototype. A camera module of Raspberry Pi is used to capture the image of highway continuously. Micro SD used as storage media and power is obtained from a Li-Ion battery. GPS and 3G modem modules is used to lock the position of the prototype when a pothole is detected. If a pothole is detected, the position of location point of potholes can be displayed on a web with Google maps API integration. The resulting prototype is shown in Figure 5.

![Prototype System Image](image)

**Figure 5.** Prototype of potholes detection

**Testing**

Testing is done with a prototype direction angle $\alpha \approx 45$ and a height $H \approx 0.5$ feet from the asphalt surface as shown in Figure 6(a), aimed for the camera is always facing toward the highway. Several scenarios carried out to test the reliability of the prototype as the position of the sun is in front of the driver, the sun is in the right or left side of the driver, and the weather was sunny and cloudy. The shape, size, condition of potholes tested is varied. Testing is conducted in Tamalanrea, Makassar, Indonesia as many as 30 locations of potholes.

![Testing Image](image)

**Figure 6.** (a) The testing process. (b) Examples of system output, blob detection successfully detect the potholes, but Neural Network classify into Not a Potholes Object
Results
The result shows the detection still indicate some failures of detection. In many cases, blob detection has been able to detect the presence of potholes based on the pattern of convexity shape. But in the process of classification of asphalt and potholes, Neural Network Backpropagation considers the output as part of the road, not the potholes. The process of neural network as determiner of potholes detection classifies the output of Blob Detection that are appropriate to be a non-potholes (not detected). The sample of output of the system is shown in Figure 6(b).

The number of detection error of Neural Network Backpropagation is assumed because the selection of training data is inappropriate. With varying conditions of asphalt, the possibility of similarity in the degree of grayscale pattern between the inside of pothole with asphalt becomes higher. This causes the detection process of potholes; especially on low-quality asphalt is fail. On the condition of pothole covered trees shadow or buildings, detection error becomes greater. This is due to the pattern of grayscale pattern of asphalt and the inside of pothole to be same.

Conclusions
The presence of pothole gives a negative impact to the people. Potholes can be driven to a fatal incident to driver and their vehicle. This situation becomes more difficult as collecting data of location point of potholes from the related agencies or the government is performed manually. Therefore, a detection system and automatic data collection of potholes that can be attached on public transport can help related agencies in conducting highway maintenance.

The results of these studies needs to be improved. It is expected to improve the accuracy and reliability of the prototype by focusing to develop on the blob detection method or by having a better training data for the neural network. The use of other intelligent methods such as Neuro-Fuzzy or add adaptive filtering process can also be another alternative.

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