Pothole detection system design with proximity sensor to provide motorcycle with warning system and increase road safety driving

Hadistian Muhammad Hanif¹, Zener Sukra Lie¹*, Winda Astuti¹, Sofyan Tan¹

¹Automotive & Robotic Program, Computer Engineering Department, BINUS ASO School of Engineering, Bina Nusantara University, Jakarta, Indonesia 11480

Corresponding author: wastuti@binus.edu

Abstract: Technology in transportation becomes important nowadays and must be developed overtime. In the era of development, there are so many roads extensions to balance the significant additions of motorized vehicles. The increasing number of vehicles caused problems such as damaged roads and lack of maintenance to the road itself. Lack of awareness to repair the damaged roads, especially potholes, make it more dangerous for riders to drive safely. This issues are more concerning right now because the increasing number of accident and mortality. To prevent accident to happen, the pothole detection sensor can be used to on car system. The development of pothole detection sensor in this research is adopted from the proximity sensor system where in that system they use camera and digital imaging process. The advantages from our system that we research and develop are more user friendly from the feasibility and the financial aspect. Low cost sensor with the same quality of the existing system is develop in this work. Despite the use of low cost sensor, the maintenance also on the lower cost and easier to do. As the result of this research and study, an error was obtained between the distance that detected the pothole should be in less than 4% distance range from the sensor.

1. Introduction. Transportation becomes a necessity in our life. This is due to the large number of our activities that require efficiency and faster mobility. Not only applied in daily use for people but also in all commodity transfer. This activity can be carried out through several modes and tracks; air, land, and sea. With the increasing mobility and transfer both human and all of the commodity, these cause an increasing number of problems in transportation.

In this study, we focus on land transportation facilities, namely roads; and the users, namely motorbikes. From the recent study, Indonesia is one of the largest motorcycle users in the world and also has a fairly high accident rate[1-2]. Several factors can cause the accidents that includes human, vehicles, roads, and environmental factors. On of factor that becomes the main concern in these research are damage surfaces and imperfect road construction.

In this research, we try to develop a system that can be used to detect potholes on road. The existing system is using a camera and digital image processing[3-7], but for motorcycle users, this technology mainly too expensive to buy, including for maintenance. To solve it, this study, the proximity sensor that being used for the system is cheaper and easier to maintain. From the data that available at the
Indonesian Motorcycle Association (AISI), in 2018, more than 6.3 million motorcycle units were sold in the Indonesian market; that showed there was an 8.4% increase in sales compared to 2017. With the existing data, it can be seen that motorcycle users in Indonesia continue to increase every year.

2. **System worked.** The design is carried out in three stages, namely the development of a pothole road recognition system, system design and testing. The stage of developing the pothole road recognition system is directed by using proximity sensors, microcontroller and using the Arduino IDE with the combination with several sensors into something more compact and efficient. The results of this development phase are intended to provide the system with the right information about road conditions to users.

After the development phase, the system continues to design stage. At this stage, a series of systems and prototypes are made. The design was done by arranging the circuit, selecting the source, placing the sensor, and also determining the parameters that will be used by the sensor. These parameters are intended to determine road conditions and vehicle speed to activate the system. Fig 1 shows a picture of the system design.

The proximity sensor is used as the main sensor to detect to potholes. In this study, the proximity sensor used a ToF (Time of Flight) sensor which based on infrared light. This sensor is a small part of the LiDAR sensor which also uses light to measure distances. The distance data from the sensor will be sent to the microcontroller for processing, and the information showed the road conditions (in front of the sensor). The secondary sensors are gyro sensor and Hall Effect sensor. The sensors were used to provide parameter data for the activation of the road hole detection system. The gyro sensor has a function to determine the orientation conditions of the vehicle and provides the data to the microcontroller, while the Hall sensor functions to get speed data from the vehicle to be used by the system.

The entire data processing was done on a microcontroller Arduino-based so the system can be easily created or modified with the Arduino program language. This kind of microcontroller is commonly used due to several benefits which are size, convenience, and features. After data processing is complete, the data will released by the system to the existing interface, so that the data can be used as information by motorcycle riders. The interface used to convey information to the user in the form of OLED LCD, LED & buzzer as a warning to inform that there are holes. LCD has a function to continuously display speed data from the motorcycle, as well as system sensor condition data; The LED & buzzer is only used to inform the driver of road holes, if the parameters in the (designed) system have been met.
For the physical design, the main system which is a voltage regulator, microcontroller (Node MCU), Gyro sensor and buzzer are placed in one box and store in bottom of the motorbike. While, the proximity sensor is placed on the front of the motorcycle (under the main light) and the speedometer (including led) on the motorcycle arm.

3. **System design.** The design was done using a NodeMCU as a microcontroller. The system gets power (12V) directly from the electric motorbike. In this design, the system was mounted by a distance measuring sensor with LiDAR, which function to detect the level of measurement of road surface distance constantly against the road. As said before, the sensor gets input power through voltage regulator module of 5V from the 12V electric motorcycle, and the sensor provides input to the NodeMCU with the Serial RX / TX Software pin. Another sensor, gyro was used to determine the elevation angle through which the system passes. The gyro sensor power input is also obtained from a voltage regulator of 5V and the sensor provides input via the I2C pin. Hall sensor was used to determine the speed of the vehicle, this sensor gets power from NodeMCU of 3V and provides data for processing NodeMCU through pin D3. Simple voltage divider is used to measure the voltage of the electric motor battery directly and is connected to pin A0. All data obtained from various sources on the system will be processed by NodeMCU and provide an output in the form of a display on the system's OLED screen which is powered by a voltage regulator of 3.3V and gets input from the I2C pin. The warning module uses LED and the Buzzer system gets power from NodeMCU and gets commands from pins D0 and D5.

4. **System work programming.** Node Mcu microcontroller programming is done using the Arduino IDE (Integrated Development Environment). Figure 2 shows a workflow system diagram. The system starts working with processing to initiate the whole system, after all system modules run normally, the system's OLED screen will light up and display the data provided by the microcontroller. The speed sensor will take vehicle speed data, if the speed exceeds or equals the speed threshold that has been set (5 km/h), then the orientation data will be used to determine whether the hole data retrieval will be done, if the position is stable, then the system will determine whether or not there are holes from the distance data which is obtained, if after processing the system determines that there is a hole in front of the vehicle, the system will turn on the warning using the LED and Buzzer. Because the system is closed, the system will re-process data and execute commands from the beginning after turning on the warning and will not stop until the electric motor is turned off or the electrical connection to the electrical appliance is cut off.
The last stage of system design is the testing phase. This stage was carried out for testing the work of the system in general, such as when the activation of the system will occur, whether according to the activation of the system with parameters given to the system such as speed so that some parts of the system are only active when the speed has passed a certain threshold and also other conditions on the vehicle will determine system output results are made. For example, the system should only give a warning using the LED & buzzer when conditions of speed, orientation and, changes in the distance in the system are suitable for activation.

After testing, the system work in general has been completed and the system can run as expected, the second stage of testing is carried out namely the measurement of hole detection results from the sensor and direct measurement through video recordings of the system that has been integrated on the electric motor, whether the system can detect holes on the road / hole in the test site for testing at a certain speed in accordance with the parameters used.

5. **Experimental Setup.** The results of the test were carried out in several stages, namely the testing of the distance sensor deviation, testing the battery voltage measurement, testing the gyro sensor, testing the hall sensor, and testing the hole detection / warning system.

The proximity sensor deviation testing was static and were not move. The sensor was placed on the platform and directed to the target and carried out during the day to ensure the ability of the sensors used. In general, the sensor used can detect distances of up to 12 meters, due to various conditions, it was carried out with the general conditions that will occur in the field with a maximum distance of 7 meters.
Figure 3 is a testing program of the proximity sensor. From the results obtained shows the distance measured by the sensor directly and the correlation of distance data obtained on the number of points captured by the sensor. These results indicate that the sensor can detect road conditions at a distance of 1m to 7 meters well. For more detailed data, see Table 1.

| Measuring Tape | Sensor data | Error | %Error |
|----------------|-------------|-------|--------|
| 100 cm         | 100 cm      | 0 cm  | 0%     |
| 300 cm         | 303 cm      | 3 cm  | 1%     |
| 400 cm         | 413 cm      | 13 cm | 3.25%  |
| 520 cm         | 510 cm      | 10 cm | 1.92%  |
| 700 cm         | 712 cm      | 12 cm | 1.71%  |
| 720 cm         | -           | -     | -      |

Table 1 Static proximity sensor test data

Calculation of errors obtained for data Table 1 above is done using the formulation of the percentage of errors where the percentage of errors is the absolute result of the difference between the data taken by the sensor, the data taken by measuring tape, and divided by data from the measuring tape, then multiplied by 100.

$$\% \text{error} = \left| \frac{\text{Sensor} - \text{Pita}}{\text{Pita}} \right| \times 100$$

From the data in Table 1, the sensor cannot detect distances that are near 720cm or greater, this can be caused by the greater amount of infrared light entering the sensor from sunlight compared to the infrared light sent by the sensor and then reflected back to can measure the distance with the speed of reflected light back.

Although the average% error result is 1.58%, for this project the maximum distance taken for the tool is around 4m to 5m to reduce the risk of errors caused by unruly variables (reflectivity by an object).
Testing the battery voltage gauge is done directly using a digital multimeter and comparing the results obtained with the results displayed by the system on the OLED screen. From the data taken, the voltage obtained has a difference that can be seen in Table 2 below. The Differences can occur due to changes in resistance in the system components, but the average % error is still relatively small.

| System | Multimeter | % Error  |
|--------|------------|----------|
| 52     | 52         | 0        |
| 51.25  | 50.88      | 0.721951 |
| 48.71  | 50.1       | 2.853623 |
| 49.01  | 48.23      | 1.591512 |
| 48.6   | 47         | 3.292181 |
| Avg    | 47         | 1.691854 |

Table 2. Data Voltage

Gyro sensors were tested by comparing the results of data provided by Gyro sensors used in the system with Gyro sensors used by public mobile phones. First, the system is connected to a computer via a USB cable, after the system is connected, the settings are made for the system by changing the order of the code of the system program that has been made using Arduino IDE.

After reprogramming is complete, the serial monitor can display the values obtained from the Gyro calculation directly for observation and data collection. In Figure 4, you can see the display of the serial monitor and the results of the data obtained.

After the data can be seen, the data is compared with the results of the Gyro mobile-phone which is placed on a flat field on an electric motorcycle. To see the difference of data, the motor is then tilted several times; the results of the data from the serial monitor and mobile-phone continue to be monitored in the test because there is no feature to store the data that is on the cellphone used for Gyro testing.

Fig. 4 Arduino monitor serial display
The numbers generated by the Gyro serial monitor have differences in decimals, but the numbers used for system work do not use decimals so the values are very close. A value of 10 degrees and above indicates that the slope has exceeded the parameters on the Gyro, so the system states that the motor is unstable.

Hall sensor is tested by comparing the speed results displayed on the speedometer with the original results on electric motor tires. This is done using 2 cameras that will record the results of the speedometer and tire rotation. To find out when a rotation occurs on a rotating motorcycle tire, white markers are placed on the end of the tire. After the data results are obtained, the tire rotation is converted to km/h speed using a simple formula.

\[ v(m/s) = \omega \cdot r(m) \]

Speed / velocity in meters per second is equal to the angular velocity multiplied by the length of the radius of the tire in meters. In tests carried out, the length of the motorcycle tire radius is 15.24cm or 0.1524m, the speed on the speedometer is held at 5km/h, and from the results of the recorded tire rotation video, the motorbike rotates 100.8 times in one minute, this result is obtained using Adobe Premiere Pro application to see changes in rotation for 10 seconds of the video, can be seen in Figure 5.

Once obtained, the rotation of every minute of a motorcycle tire is converted to angular speed using the formula.

\[ \omega = (\theta_f - \theta_i) / t \]

The angular velocity is equal to the final angle minus the initial angle divided by time. Each rotation angle is 360 degrees, the angle is changed to units of radians which is \(2\pi\) and the time taken is 60 seconds, so it is obtained.

\[ \omega = (100.8 \cdot 2\pi) / 60 \]

\[ \omega = 3.36\pi \text{ atau } 10.556 \]

Because the angular velocity has been obtained, all existing variables can be entered into the formula to find the speed.
\[ v(m/s) = 10.556 \cdot 0.1524(m) \]
\[ v(m/s) = 1.608 \]

So the speed obtained is 1.608 m/s or 5.79 km/h. The speed on the speedometer that was made could not display the decimal number so that the difference data could not be seen with the data obtained on the motorcycle tire video recording because the difference was less than 1 km/h. The following results are obtained in Table 3 below.

Testing is done dynamically or in motion but under regulated conditions so that data retrieval can be consistent. The motor moves as fast as 5 km/h in a straight line with an artificial measuring tape made of paper towards the stairs going down the terrace as a hole to be detected, the height of the hole is limited by a rectangular paper barrier without a lid measuring 7.5 x 23.7 cm with a wall height of 3 cm.

In testing, the motorbike was ridden by 2 people as the rider and also the camera holder to get data from the system that was installed. The total load of the driver and passengers is around 120 kg, so the sensor position is 73 cm from the ground with a depression angle of 16 degrees. The distance recorded by the sensor is around 256 cm to 273 cm, so the original distance is around 254 cm to 262 cm.

| Video Data | Spedometer | % Error |
|------------|------------|---------|
| 5.79       | 5          | 13.64421|
| 9.82       | 9          | 8.350305|
| 4.48       | 4          | 10.71429|
| 8.62       | 8          | 7.192575|
| Avg        | 9.975345   |         |

Table 3. Data Velocity

Testing was done dynamically or in motion but under regulated conditions so that data retrieval can be consistent. The motor moves as fast as 5 km/h in a straight line with an artificial measuring tape made of paper towards the stairs going down the terrace as a hole to be detected, the height of the hole is limited by a rectangular paper barrier without a lid measuring 7.5 x 23.7 cm with a wall height of 3 cm.

In testing, the motorcycle was ridden by 2 people as the rider and also the camera holder to get data from the system that was installed. The total load of the driver and passengers is around 120 kg, so the sensor position is 73 cm from the ground with a depression angle of 16 degrees. The distance recorded by the sensor is around 256 cm to 273 cm, so the original distance is around 254 cm to 262 cm.

In testing, the sensor will detect a change in distance of 3 cm which then increases after passing through the paper barrier so that the warning system will work 2 times, when touching 3 cm and after passing through the barrier. From the location of the motorized testing site, the cellphone is placed on a tripod and records a few meters to the end of the path to see at what distance the measuring tape is stretched, the system works compared with assuming the distance with the percentage error sensor.
plus 3cm from the paper barrier. After testing is complete, the system video results and video results from a tripod are compared to find out when the system is working.

In both videos, the buzzer sound can be heard when the motor is at ±25cm before the 300cm mark which is on the measuring tape, so the detection results are around ±275cm at a speed of 5km/h. The data obtained produces a clear possibility of error in the system of ±0.73%.

6. Conclusions. This research gives good results as intended. In the future, the results of this research could be made as a prototype and tested directly on the road to find out whether there are still weaknesses to be repaired and develop. This research is expected to become an appropriate technology that can benefit the community and can reduce the accident and the mortality rate due to damaged road.

7. Reference
[1] A. Wibowo, “Analisa Kecelakaan Lalu Lintas Pada Ruas Jalan Utama di Wilayah Kabupaten Sragen Tahun 2002-2006”, Universitas Muhammadiyah Surakarta, 2010.
[2] Saputra, D, “Studi Tingkat Kecelakaan Lalu Lintas Jalan di Indonesia Berdasarkan Data KNKT (Komite Nasional Keselamatan Transportasi) Dari Tahun 2007-2016”. Jakarta:KNKT, 2017.
[3] J. Lin and Y. Liu, “Potholes Detection Based on SVM in the Pavement Distress Image,” 2010 Ninth International Symposium on Distributed Computing and Applications to Business, Engineering and Science, 2010.
[4] S. Joseph, “ROLE OF ULTRASONIC SENSOR IN AUTOMATIC POTHOLE AND HUMP DETECTION SYSTEM,” International Journal of Scientific & Engineering Research, 8, 260–265, 2017.
[5] R. Madli, S. Hebbar, P. Pattar, and V. Golla “Automatic Detection and Notification of Potholes and Humps on Roads to Aid Drivers” in IEEE sensors journal, 4313-4318, 2015.
[6] M. H. Yousaf, K. Azhar, F. Murtaza, F. Hussain, “Visual analysis of ashalt pavement for detection and localization of potholes.” Advance Engineering Informatics, 88, 524-537, 2018.
[7] Y. O. Ouma, M. Hahn, “Pothole detection on asphalt pavements from 2D-colour potholes images using fuzzy c-means clustering and morphological reconstruction,” Automation in Construction 813,196-211, 2017.
[8] A. Tedeschi, F. Benedetto, “A real-time automatic pavement crack and pothole recognition system for mobile Android-base devices.” Advance Engineering Infomatics, 32, 11-5, 2017.
[9] T.Kim and S.K.Ryu, “Review and analysis of pothole detection methods”, J. Emerging Trends Comput. Information Sci, 5, 603-608,2014