Remote Sensing of Potholes and Measurement of Pothole Volume using Ultrasonic Sensors

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Abstract - *The main objective of the project is to design and fabricate a Sensor system which will detect the Potholes on the road and will measure the volume of those Potholes, which is needed for the levelling process under maintenance activity of the road.*

This is done using Ultrasonic sensors mounted on the front of a vehicle such as baby stroller. Sensors on the front of the vehicle is allowed to sense the surface of the road, the Sensor measures the vertical distance from the sensor to the road surface at a rate of 20readings per second. The Sensor data is stored in the ROM of the Arduino controller. This data is retrieved and analyzed using either MS Excel or any Cloud based platform for data analytics. Ultimately, after the analysis, the volume of Potholes and correspondingly the volume of filling can be accurately estimated.

Key Words: **Arduino, Ultrasonic Sensor, Pothole volume, Maintenance Cost, IOT**.

1. INTRODUCTION

Roads make a crucial contribution to economic development and bring important social benefits. They are of vital importance in order to make a nation grow and develop. Roads open up more areas and stimulate economic and social development. For those reasons, road infrastructure is the most important of all public assets. But due to repeated loading and weathering on roads, a **pothole** may be caused which may affect the human life very badly.

A **pothole** is a structural failure in a road surface, caused by failure primarily in asphalt pavement due to the presence of water in the underlying soil structure and the presence of traffic passing over the affected area.

So our project helps the society in promoting the road safety and to reduce the difficulties in detecting the pothole and also reduce the usage of human power and saves the time. Our project addresses the identification and measurement of its volume, Therefore the pothole on the road (Fig-1.Pothole) may be identified and filled completely and hence the accidents occur due to the pothole may be reduced.

Fig-1: Pothole

1.1 Conclusion

The objective of this project work has been framed into chapters for exhibiting the sequential order of our project. The basic C programming and design calculations along with photos have been included in the following chapters.

2. LITERATURE REVIEW

2.1 Introduction

Before starting this project, it is important to research existing machines and the technologies used in them. This will help us understand any existing problems and try to find solutions for these problems in such a way that it can be implemented in our project. Going through the literature also helps us understand the practical outcomes of the project and how to attain the required outcomes.

2.1 Pothole-Definition

IRC established a basic requirement for the scope of potholes to be repaired. An expanded definition included other variations that would be encountered in practice.

2.2 Pavement Type

The pothole would be of flexible base or rigid composite base.

2.3 Pothole Size Limits

1 to 6 inches (2.5 to 15 cm) in depth, 1 to 10 square feet (.09 to .93 sq m) in surface area.

2.4 Pothole Frequency and Location

Closely spaced or infrequent. Anywhere in 10to 1*2* foot (3 to 3.66 m) lane width but usually in wheel paths assumed to be 7 feet.

2.5 Repair Conditions

It should be the objective to make repairs in virtually any weather condition, day or night time operation whenever potholes develop.

2.6 Automated Patching

An operational requirement was that the system be productive and place as much material per day as possible, with less labour, and at lower cost. The overall design of the system and many of the engineering decisions depend on calculated operational and maintenance costs. There are many sources of information for determining the cost of various patching operations.

The primary economic drivers include the cost of materials, labor rates, productivity of patching operations, costs of delays, and patch lifetimes. No single source was found that could bring all of these costs into a single comparison. For this reason, we developed a productivity model to analyze how pothole patching costs are related and used it as a tool to evaluate the impact of some engineering decisions on finalpatch cost.

2.7 Sensors

Sensors convert environmental conditions into electrical signals. An environmental condition might be a mechanical, optical, electrical, acoustic, magnetic, or other physical effect.

2.8 Benefits

The technology developed and applied through this study will have lasting benefit to all roadway maintenance authorities and workers by making pothole repair safer for all, with greater performance and productivity than traditional methods. Given a successful commercialization program and field testing, production models could start to become available for the benefit of the pavement maintenance community in 1994. We think that different configurations would be manufactured to maximize the benefit to state highways, districts, cities, and private contractors. Every group has special requirements as to size, maneuverability, level of automation, and material capability.

2.9 Conclusion

Thus, research was done regarding this project on various sources of literature. The many methodologies were studied and this information has helped to complete the project successfully.

3. SYSTEM DESIGN

3.1 Introduction

This System helps the society in promoting the road safety and to reduce the difficulties in detecting the pothole and also reduce the usage of human power, and hence saves the time.

This is done in ensuring perfection in all the aspects such as speed, accuracy, flexibility, safety, reliability and cost effective during the maintenance. The overall concept of the system will be explained in this chapter.

3.2 Ultrasonic Sensor

An Ultrasonic sensor is a device that can measure the distance to an object by using sound waves. It measures distance by sending out a sound wave at a specific frequency and listening for that sound wave to bounce back. By recording the elapsed time between the sound wave being generated and the sound wave bouncing back, it is possible to calculate the distance between the sonar sensor and the object.

3.3 Arduino Atmega-328

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano 3.0) or ATmega168 (Arduino Nano 2.x). It has more or less the same functionality of the Arduino, but in a different package. It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one.
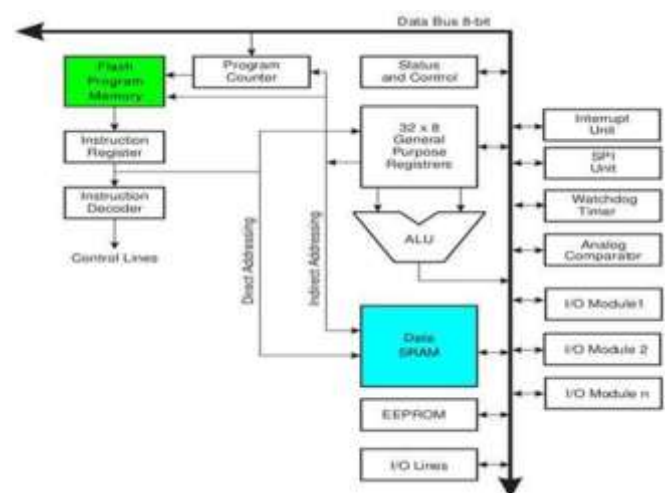

Fig.2: Architecture of Arduino Atmega-328

3.4 Power

The Arduino Nano can be powered via the Mini-B USB connection, 6-20V unregulated external power supply (pin 30), or 5V regulated external power supply (pin 27).

3.5 Memory

The ATmega-168 has 16 KB of flash memory for storing code (of which 2 KB is used for

Boot loader); the ATmega328 has 32 KB, (also with 2 KB used for the bootloader). TheATmega- 168 has 1 KB of SRAM and 512 bytes of EEPROM (which can be read and written with the EEPROM library); the ATmega328 has 2 KB of SRAM and 1 KB of EEPROM.

3.6 Input and Output

Each of the 14 digital pins on the Nano can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

3.7 Serial

0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the FTDI USB-to-TTL Serial chip.

3.8 External Interrupts

2 and 3 pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.

3.9 PWM

3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analogWrite() function.

3.10 SPI

10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language.

3.11 LED

There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the though is it possible to change the upper end of their range using the analogReference() function LED is on, when the pin is LOW, it's off. The Nano has 8 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts.

Fig -3

3.12 Estimation Table

The following table shows the Cost estimation of this project

TABLE 1: Cost Estimation

S.NO	COMPONENTS	QUANTITY	COST
1	Arduino Atmega-328	1	220
2	Ultrasonic sensors	2	300
3	Wheels	4	280
4	Metal body	Fully	1000
5	Additional cost	-	500
		TOTAL	2300

3.13 Conclusion

The various functionalities and principles used in the Project have been explained. The entire working of the Sensor system has been described. Further details will be seen in the following chapters.

4. PROGRAMMING CONCEPTS

4.1 Introduction

For the detection of the pothole and to measure the vertical distance automatically when the pothole is detected, programming is done using Embedded C language in Arduino portal.

4.2 Arduino Programming

```
int trigPin = 9;

int echoPin = 10;

void setup()

{
```

```
Serial.begin(9600);

pinMode(trigPin, OUTPUT);

pinMode(echoPin, INPUT);

}

void loop()

{

long duration, distance;

digitalWrite(trigPin,HIGH);

delayMicroseconds(1000);

digitalWrite(trigPin, LOW);

duration=pulseIn(echoPin, HIGH);

distance =(duration/2)/29.1;

Serial.print(distance);

Serial.println("CM");

delay(10);

}
```

4.3 Conclusion

Thus the control of the Sensor and the Arduino Nano MC board operations programming is done in Arduino portal using basic C language.

5. ANALYSIS AND RESULTS

We have calculated the Volume of filling or Volume of each Pothole manually using Prismoidal formula. It can be even done using Trapezoidal formula. Comparatively, Prismoidal formula is more accurate and reliable and hence we used it to calculate the volume. In the following table, Volume calculations for two potholes have been shown.

Experimental details:

Average Speed of the device/vehicle= 5 kmph= 1.389 m/s

Frequency of measurement by sensor= 20 per second

Interval between two successive measurements= (1.389/20) x 100= 6.945 ~ 7 cm

S.No	Pothole	Vertical distance(cm)	Interval (cm)	Volume (cm³)
1	1	5	7	1880.247
2		10	7	
3		6	7	
4		4	7	
5	2	6	7	1249.823
6		8	7	
7		7	7	

Prismoidal Formula= (Common distance/3) x (Area of First Section + Area of Last Section + 2(Sum of Even Sections) + 4(Sum of Odd Sections))

For Pothole-1:

R1=5; A1= Semi circular area with R1 as radius= 39.27 cm^2

R2=10; A2= Semi circular area with R2 as radius= 157.08 cm^2

R3=6; A3= Semi circular area with R3 as radius= 56.55 cm^2

R4=4; A4= Semi circular area with R4 as radius= 25.13 cm^2

Volume=7/3(39.27+25.13+2(56.55)+4(157.08))= 1880.247 cm^3

For Pothole-2:

R1=6; A1= Semi circular area with R1 as radius= 56.55 cm^2

R2=8; A2= Semi circular area with R2 as radius= 100.53 cm^2

R3=7; A3= Semi circular area with R3 as radius= 76.97 cm^2

Volume= 7/3(56.55+76.97+4(100.53))= 1249.823 cm^3

6. CONCLUSIONS

Our system is efficiently designed to fulfill two main criteria; First one being detecting potholes on the road and second is to calculate its volume. The cost-effective system that we have proposed will prevent accidents to a great extent. Our proposed solution makes use of a better and more efficient technology to detect potholes and warn the driver about them so that he is aware a prior.

There is no existing technology for this, hence this system would be time efficient and would consume lesser power. As there would be database comprising of the location of the potholes, it will notify the government authorities and in turn necessary action can be taken.

As we can extend the project in future by integrating it with GPS systems and real time satellite feed, it will help the commuters have a prior idea of the potholes on the path and make them conscious of their route enabling a safe travel.

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