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Road Quality and Condition Detection

Using GPS and a Raspberry pi

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***Abstract*—The aim of this project is to reduce the number of road accidents occurring due to bad roads, additionally it also provides vital information on the quality of roads which can be used while laying new roads. A model car is designed with all the necessary sensors placed in it, the car is then driven around on existing roads where it records the road information. The information initially collected is made available for all users using navigation systems. The driver is alerted when nearing an inconsistency in the road. Designed and implemented using GPS and a Raspberry pi.**

***Keywords*— GPRS, Accelerometer, ultrasonic sensors, PIC16F871 microprocessor.**

I. Introduction

This paper is aimed at implementing a novel system to detect, store and warn the forthcoming inconsistencies. In hilly areas and during bad weather conditions the road ahead is not clearly visible to drivers which make vehicles prone to accidents. There is insufficient knowledge about the location and the type of inconsistencies. This system provides a solution by warning the motorist in real-time, it also doubles up by collecting the road quality data which is used while laying roads thereby this system reduces additional surveys. This system is self-learning and recursive system which requires less human involvement.

II. Ground Penetrating Radar

Ground Penetrating radar(GPR) is a high speed,[1] continuous and noninvasive tool that is used to map subsurface conditions in a wide variety of applications like identifying defects in pavements [4] and bridge decks, detecting the corrosion of reinforcing steel in concrete and locating moisture damage. This type of system is well suited for detecting anomaly in roads. GPR maps changes in the underground profile, this is done by using the contrasts in the electromagnetic conductivity across material interfaces. The block diagram is clearly given in the fig.1.

GPR sends short electromagnetic pulses downward into the ground, [2, 3] these pulses are reflected back to the receiver antenna where amplitudes and arrival times are recorded. One-Dimensional electromagnetic wave propagation theory is used in analyzing the reflected pulses. The amplitudes and arrival times of reflected pulses are correlated to the electrical conductivities (dielectric constants) of the material layers. Part of the energy is absorbed across material interfaces and the remaining is reflected the amount of absorption and reflection is dependent on the dielectric contrast of materials. The observed crests in amplitude of the reflected waves in their order of occurrence can be denoted as the antenna end reflection (A_0), the surface or road (asphalt) reflection (A_1), the base reflection (A_2), and the subgrade reflection (A_3), respectively. The time interval (t_1) between peaks A_1 and A_2 represents the round trip travel through the pavement layer. [4] Similarly, the time interval (t_2) between peaks A_2 and A_3 denotes the round trip travel time through the base layer. [5] The thickness of each layer (hi) can be calculated as:

$$h_i = (v_i t_i) / 2$$

Where: v_i = propagation velocity through each layer

The propagation velocity is correlated to the electromagnetic behavior of the material:

$$v_i = c / \sqrt{\varepsilon_i}$$

where: ε_i = dielectric constant of each layer

c = speed of light in air (0.30m/ns)

The values of Dielectric constants and pavement material details are given in table 1.

The block diagram of the GPR prototype with its major components is depicted in figure 1. It has two sections a microprocessor based electronics section and a microwave section. The electronic part of the system controls the GPR's operation to perform data acquisition and processing, and to display the measured results. The microwave section consists of a receiver, a transmitter, and receiving and transmitting antennas. The pulse generator of the transmitter generates a mono-cycle pulse of 1 nano-second pulse width. The pulse is amplified by the power amplifier and is radiated by the transmitting antenna. The reflected signals from the surface and subsurface are collected by the receiver antenna and then processed by the sampling head to produce a low-frequency signal. This low frequency signal, containing information of the subsurface conditions, is then amplified by the IF amplifier

III. GPR-Antennas

A variety of microwave antennas can be used in GPR systems, the frequency and the type of antenna needed should be decided as per the requirements. Widely used antennas include TEM horn antenna and micro-strip horn antenna. Both the transmitting and receiving antennas should be identical and they must be separated by a metal plate.

We propose the use of micro-strip horn antenna for estimating the road quality due to advantages like:

- Broad bandwidth, the wide bandwidth antenna allows wide-band signals, e.g., narrow pulses covering decades of bandwidth, to be transmitted and received more completely than known antennas. More power of the signal can therefore be transmitted and received. Moreover, more information reflected from the subsurface can be captured.
- There is a small coupling between the two antennas when used in a transmitting and receiving antenna system, even when they are next to each other and no absorbing material is used. This unique feature is good for radar applications where the antennas need a certain degree of isolation between them.

The frequency of the antenna should also be decided according to the requirement. In our case since the sole purpose of the system is to scan the pavement and the layer beneath it we have opted for a 1000 MHz primary antenna (transmitting antenna) and 900 MHz for the receiving antenna to obtain a scan depth of 50 – 60cm with decent resolution. The characteristics of the antenna are explained clearly in the table 2. The higher the frequency the shallower the frequency penetrates but at the same time lower frequencies limit the resolution of scans.

IV. IMPLEMENTATION

This system is divided into two parts where one analyses the road condition whereas the other records the road quality.

A. Road Condition detection

The fig.2 giving the block diagram of system. The system that analyses Road condition includes components such as Arduino Mega 2560,GY-521 Accelerometer,HC-SR04 ultrasonic sensors, Ublox Neo 6MV2 GPS and a Raspberry pi.

The ultrasonic sensors give the distance between the vehicle and the road, this distance is constant all the time with minute variations whereas when a pothole or bump arrives the distance increases or decreases respectively. All the three ultrasonic sensors are powered by 5v vcc and ground obtained from the Arduino. The echo and trigger pins are individually connected to the digital pins in the Arduino Mega 2560. The sensors are individually pinged continuously to obtain the raw values. These values are then processed to obtain the distance in cm.

The Accelerometer is used to measure the pitch and roll of the vehicle which gives information regarding the road inclination. The GY -521(MPU 6050) accelerometer is powered by 3.3v vcc obtained from Arduino Mega 2560. The data transfer to Arduino is done through I2C protocol where the SCL and SDA pins of Accelerometer module are connected to SCL and SDA pins of Arduino respectively. GY-521 module provides the 3 axis accelerometer values along with the gyroscope values, only the accelerometer values are read from the module which are then further processed and calibrated according to the requirement.

The data is continuously collected and processed to detect the irregularities, the collected data is forwarded to the raspberry pi using USB which doubles up as a power source for Arduino Mega 2560. A python script is run in a loop on Raspberry pi, this script receives the serial data and tags it with the latitude and longitudes from GPS and stores it in a SQLite database. Baud rate of 38400 is used for serial communication.

The GPS module used is ublox neo 6m-v2 module which has its own antenna and data processing system. It is powered using 5v supply obtained from the GPIO header pins on the raspberry pi, the data transfer is through SPI protocol.

The database obtained is further queried using python script which passes the coordinates of irregularities along with other information to a web UI which uses the existing google maps to mark pointers.

The system uses two software codes, one for the Arduino 2560 and the other for the Raspberry pi.

The code on Arduino can be summarized as follows by the pseudo code.

- Start the serial port and check if the device is ready to receive data.
- Read the accelerometer values.
- Ping the ultrasonic sensors and obtain readings.
- Process the raw values obtained.
- Add the data obtained to a string.
- Serial print the string obtained.

The script on raspberry pi can be summarized as follows.

- Start GPS, wait till GPS is initialized and locked for the coordinates.
- Serial data received is filtered to remove duplicates and lost data packets.
- Data is stored in database along with coordinates.
- Database is searched for inconsistency and plotted on a map.

B. Road Quality Detection

The system that analyses the road quality includes a 1GHz transmitting and 900 MHz receiving antenna, microwave pulse generator, microwave frequency amplifier, PIC microprocessor and a raspberry pi.

The setup is positioned such that the transmitter and receiver antennas are facing the ground with a separation of 10cm, this separation allows scanning on rough and irregular roads. The nano second pulse generator generates 1GHz microwave signals that are transmitted through a 1GHz micro strip patch antenna. The receiver antenna collects the reflected waves from the ground, an amplifier is used to amplify the signals to milliwatt. The received signal is continuous which is sampled by sampler, the output of sampler is further amplified if necessary before being fed to the PIC16F871 microprocessor. The microprocessor analyses the raw data and

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performs operations to convert into meaningful data that can be interpreted by humans. The data collected is sent to Raspberry pi that tags the information with the GPS coordinates and stores it in a database.

V. Experimentation and Results

The design has been implemented using the Ardunio board which interface with the GPS using Raspberry Pi. The design is simulated in software and implemented practically in the car on the road via Vellore Katpadi to Chitoor district of Andra Pradesh. So we found the Bumps and patholes on the road. The simulated results are shown in fig. 4, 5, 6, 7, 8. And the measured patholes and bumps are shown in the fig. 9a and fig. 9b.

Conclusion and Future Plan

We have designed, tested and prototyped the road condition detection system which worked well in our tests on existing roads with an overall accuracy of 80%. The system was proven to be robust and error free even during long hours of testing. The system can be further improved by implementing advanced algorithms for detection and by use of more sophisticated sensors.

The GPR system was theoretically designed due to constraints in fabricating the antennas and time duration. The system can be designed in the future and changes can be made if required.

Both the systems can be clubbed together into a single system by redesigning all the components thereby making it much more portable and reliable. It can also be made more energy efficient by using low power devices.

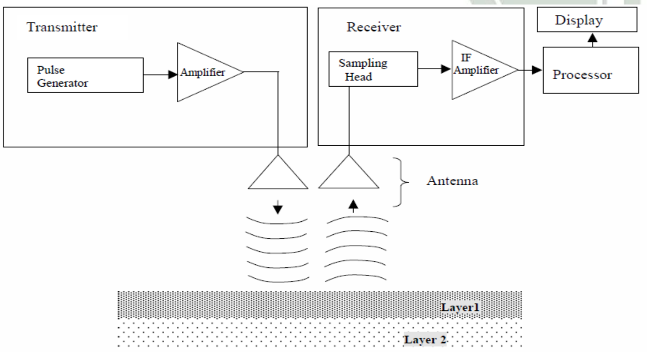

Fig. 1. GPR Block diagram.

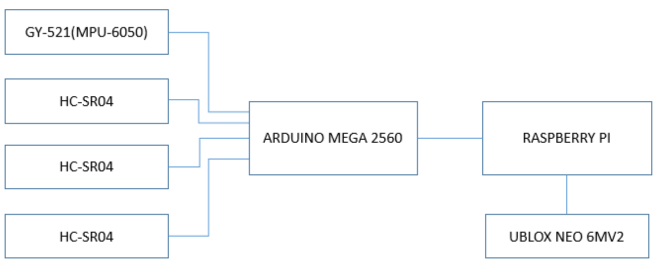

Fig. 2. Block diagram.

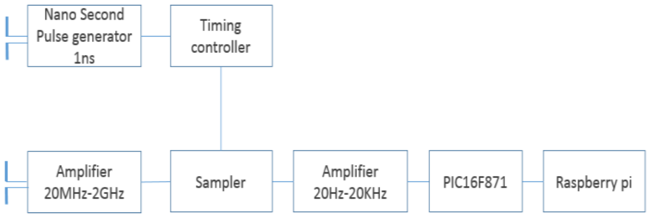

Fig. 3. Block diagram.

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