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A nondestructive sensing robot for crack detection and deck maintenance

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Abstract—Most of the developing countries, mainly depends on the public transport.It is important to maintain the roads and bridges to save the human life.Traditionally a human inspector visits the damage inroadshe/she will not cover the total area due to lack of human visual leads to limp of life.We propose a crack detecting robot that uses the infrared, ultrasonic and vibration sensor that detect the crackon the superstructure.

Ultimately, we used Kielbythe arm processor to make an interface with sensors and GSM. It produces the exact result about the crack with high accuracy and sends the message about the detection of crack to the inspector. It covers the total area of the roads and bridges by the mechanical sliding. We validate our proposed system through both simulations and experiments.

Keywords: roads and bridge cracks, Kiel, infrared, ultrasonicAnd vibration sensor, GSM, Robot.

I. INTRODUCTION

Road transport is the economic development and easy accessibility and door to door service and reliability have earned road transport and increasingly higher share of both passenger and freight traffic. Transport sector accounts for a share of 6.4% in India's (Gross domestic product) GDP.People with hand tools, oxen mules did the work of these machines people working on the national road were paid as little as $6.00 per month. Nowadays road transportation has become an integral part of the society mainly peoples depends on the public trasnportaionin order to move from one place to another place it became their livelihood. Fortrading and for theirbusiness. Roads are the only common transport system in which all kind people were using. Road transport is vital to India's economy.Road transport has not gained in importance over the years, despite significant barriers and inefficiency in interstatefreight and passenger movement compared to railways and airlines.

The main highways running through the length and breadth of the country connecting major ports, state capitals, largeindustrials and tourist centers, etc. NationalHighways in India are designated as NH followed by the highway number. Indian national highways are further classified based on the width of the carriageway of the highway. Road infrastructure provides a fundamental foundation for the performance of all national economies, delivering wide a range of economic and social benefits. Adequately maintaining road infrastructure is essential to preserve and enhance those benefits. The importance of maintenance needs to be recognized by decision makers, funded appropriately and well managed to ensure maximum value is achieved .Inadequate levels of investment or poor management of the road network will have serious consequences for economics and social wellbeing.

India has a road network of over 4,689,842 kilometers (2,414,134 meter). It is the second largest national highway in the world.National highway has the total kilometer of up to 92,851 kilometers,state highways has the total length of 1,63,898 kilometers,Major and other district roads has the length of 17,05,706 kilometers,Rural road has the total length of up to 27,49,805 kilometer.

The main roads in India are under huge pressure and in great need of modernization in order to handle the increased requirement of the Indian economy.In addition to our maintenance, the expansion of the network and widening of the existing roads is becoming increasingly important.This would enable the roads to handle the increasedtraffic, and also allow for a corresponding increase in the average moment in the speed of India'sroads.The world health organization, compilation of road network safety data for major economics found in India to have the highest number of fatalities in the world, with 105,000 road accidents caused deaths in 2010.Poor rural roads and traffic congestion in the cities remains the challenge in India.

Crack develop in highway concrete structures and pavements due to the extra loading as being responsible for generating the majority of the tensile stresses in a material, much of the cracking in concrete can be used to an intrinsic volumetric instability or the deleterious chemical reactions. The volume instability results in response to moisture, chemical and thermal effects. Inaddition, variousdeterioration chemical reactions involving the constituents of concrete or embedded materials can play significant roles causing localized internal expansions.

The impact of cracking on durability,especially corrosion is determined many transportation structures. In particular, cyclic or

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tidal exposures initiate drive-wet cycles and provide a constant source of salts to enter the cracks, significantly exacerbating deterioration. Similarly, cracked concrete in contact with sulfate rich soil can lead to accelerated sulfateattack. The complex relationship between cracking and accelerator deterioration are unique to each situation and are not well understood. Thus, considerable attention is needed from the research community to fully understand the principles involved, and transfer them to the practicing engineering community for improved durability. Types of cracks that commonly occur in the roads. [1]Fatigue or alligator cracks are interconnected cracks that are cost under the influence of repeated traffic loading. Roads that face extreme climates and heavily loaded vehicles undergo severe fatigue cracking

[2] Block cracking inroads is in the form of interconnected rectangular cracks. Thesetypes of cracks also cause roughest water seepage to the cracks. [3]Longitudinal and transverse cracking crackformed in the direction of the traffic flow are termed as longitudinal cracks and those that are formed perpendicular to the traffic flow are called transverse cracks. [4] Corrugation and shoving it is the form of sudden waves in the road surface and is perpendicular to the direction of flow and is mostly located at the points where a vehicle starts or stops on the road. It causes roughness and discomfort to the driver. [5]Depression is the localized road section with a slight depression, causes roughness and collects water which may lead to pothole formation.[6]Potholes are bowl-shaped depression of varying size in the pavement surface. They generally have sharp edges .They are most likely to occur on the road with the thin surface course. They are usually caused when the severity of cracks increases. They cause roughness and rider discomfort and are a major of accidents, especially at dark times when the visibility is very low. [7] Raveling is the crumpling up of the asphalt layer as the result of the disintegration between aggregate particles and the asphalt binder. It causes roughness and skid resistance problem and may lead to pothole formation as the moisture infiltration increases because of the openings. [8] Rutting is identified as the slight depression, along the wheel paths in the pavement .It is classified into mix rutting and sub grade rutting. [9]Water bleeding occurs when water seeps out of the joints or cracks or through an excessively porous HMA layer. [10]Stripping is the loss of bond between aggregates and asphalt binder that typically begins at the bottom of the asphalt layer and progresses upward. When stripping begins at the surface and progresses downward it is usually called raveling.

II. LITERATURE REVIEW

The literature of the existing system were used various different crack detecting methods and algorithms. Initially thermal, visual, dielectric and acoustic sensors are used. Itproduces better accuracy and greater reliability. Performance and lifetime of the sensor are low.

Secondly a charged coupled device is used for detecting the crack in fatigue and sewer pipes. It is used along with the camera scanning device. There arises an illumination problem in dark environment.

Thirdly shock observer device and vibration sensor are used so that the space and leakage is also being detected.For detecting the crack in pipelines the full automated mobile pipeline, exploration robot (FAMPER) is used, but it is sensitive to heat exploration.

Complete coverage path planning algorithm is used for covering the total area of the field automotive turning of the robot is not possible.LED and LDR combination of sensor is used for detecting the exact location of the crack and it consumes less power but it is not programmed to operate in different lightening condition.

Common 5V LED and cadmium supplied LDR was found to be sufficient. The LED is powered using one of the digital pins of the Adriano. The LDR and a 45kΩ resistor form a potential divider arrangement. The output of the potential divider is given to one of the analog input channels of the Arduino. Micro electro mechanical switch(MEMS).It can operate in both ballast and slab tracks which detect the shakes of the structure. Replaces the wireless sensor into a solar sensor for energy conservation.



Figure-1: Manual Inspection of Crack on Roads

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Usually a trained engineerinspects the crack on the super structure due to the prone human error'sseverity of the crack is not detected and it cannot produce the best accuracy in the result. It is a dangerous job while passing traffic on roads. Manual inspection is slow and it takes long time to cover the entire structure. Due to the different lightening condition the work can be done only in daytime. The inability to physically examine all parts of the bridge, solelydepend on the expert knowledge of the bridge inspector. Moreover, it requires proper training of the human resource and overall it is not cost effective.

More number of instruments and manpowerare needed to detect the crack. Improper measurementof crack may lead to dangerous accidents and disaster the livelihood of people. Due to the lack of detection danger may go severe.

III. PROPOSED METHOD

Due to different lightening conditions, illumination, low stability to withstand in high temperature system produce poor results in detection of crack.

To overcome the drawback we proposed a robotic system called nondestructive sensing robot for crack detection and deck maintenance.

In this we have used infrared and ultrasonic sensor along with ARM processor. Ultrasonic sensor which uses the sound wave for identifying the obstacles and take a different path to avoid the accidents.

Infrared red sensor which emits the infrared radiation and identifies the crack on roads.ARM processor uses an orthogonal instruction set computer for performing the functions and instructions.

4 wheel DC motor is used for carrying the robot and move over the workplace. It is controlled by the arm processor instructions and commands.

All the sensor, DC motor circuit, GSM instructions and commands are preprocessed in the ARM processor by the Kiel compiler.

GSM (Global Positioning System) is used to transfer the message about the presence of crack to the commander or an operator.

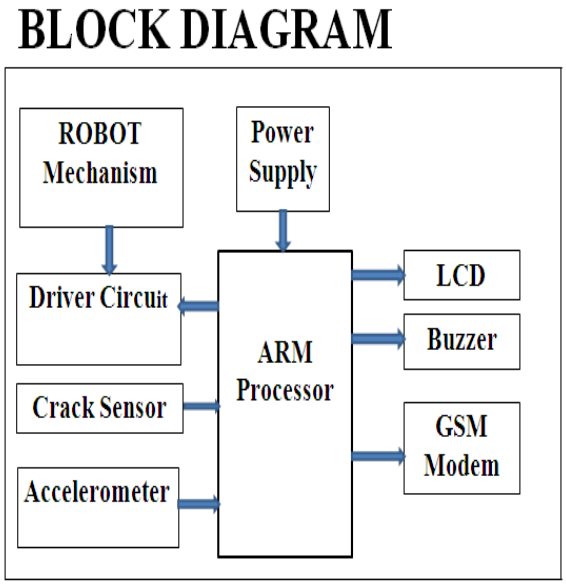


Figure-2: Block diagram of crack detecting robot

The ARM processor is a 32-bit microprocessor developed by advanced RISC machines. It is a load and store architecture and follows an orthogonal instruction set. It follows 64 and 32bit single cycle execution. Sensor instructions and 4 wheel DC motor instructions are stored on the ARM processor using Kiel software

IV. SENSOR OPERATIONS

Sensor programmers, for ultrasonic and infrared sensor are installed on the micro kit. Infrared sensor is used for detecting the crack on the superstructure.

Firstly infrared and ultrasonicsensor are placed above the moving robot. Both the sensor will emit the radiation continuously once it detect the own operation, it will perform the operation.

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Infrared sensor will emit the infrared radiationon the road once it identifies the shakes or over illumination of radiation it detects the crack by instruction stored in the processor.

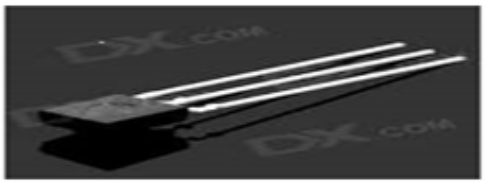


Figure-3: Infrared sensor transmitter

Once the infrared sensor program has been called the GSM program will be on alert. After detecting the crack it will send the signal to the processor and activate the GSM program signal.
GSM will send the stored message like “CRACK IS DETECTECD” is forwarded to the user by using the SIM card facility.



Figure-4:Infra red sensor receiver

Ultrasonic sensor uses the sound waves that continuously emit the sound waves. When the signal gets interact with the object and make an echo signal back to the sensor. It senses the echoed signal and compared it with the transmitted signal length.
By measuring the signal strength the obstacle distance is identified. In our project ultrasonic sensor is placed in the robot structure and emits the sound waves.



Figure-5: Ultrasonic sensor

When the vehicle crosses the robot or along the path are identified by programming. Once the obstacle identified, then the robot takes a left or right depends upon the program in processor.
Due to the presence of ultrasonic sensors, various accidents of the robot are prevented so that the manpower to operate the robot is also being reduced.
A program to take left and right is also installed in the arm processor with the instructions of the ultrasonic sensor robot take the different path.

V. SENSOR PROGRAMS

INFRA RED SENSOR

```
Task main ();
{
taskcheck_sensors()
{
While (true)
{
If (INFRA SENSOR_1 == 1)
{
Acquire (mathematics);
```


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```
OnRev (OUT_AC, 75);
Wait(500);
OnFwd(OUT_A, 75);
Wait(850);
Release (mathematics);
}

ULTRA SONIC SENSOR

Task main();
{
taskcheck_sensors()
{
While
 (True)
{
If (ULTRA SENSOR_1 == 1)
{
Acquire(SENDMutex);
Wait(500);
OnFwd(OUT_A, 75);
Release(moveMutex);
```

VI. DC MOTOR OPERATION

DC motor is a device that converts direct current (electrical energy) into mechanical energy.DC motor is a fairly simple electric motor that uses electricity and a magnetic field to produce torque,which causes it to turn. At its most simple, it requires two magnets of opposite polarity and an electric coil which act as an electromagnet.

The repellent and attractive electromagnetic forces of the magnet provide the torque that causes the motor to turn.

A DC motor requires at least one magnet, which switches the current flow as the motor runs, changing its polarity to keep it running.

The other magnet can either be permanent magnet or other electromagnet. Often the electromagnet is located in the center of the motor and turns within the permanent magnet, but this arrangement is not required.

The two outer magnets are permanent, one positive and one negative. For example, left magnet is negatively charged and the right magnet is positively charged.

VII. WORKING OPERATIONS

A DC motor is equipped with magnets, either permanent magnet or electromagnetic windings, that produce a magnetic field. When current passes through the armature, also known as the coil or wire, placed between north and south poles of the magnet, the field generated by the armature interacts with the field from magnets and applies torque.

In a DC motor the magnet forms the stator, the armature is placed on the rotor and a commutator switches the current flow from one coil to another.The commutator connects the stationary power source to the armature through the use of brushes or conductive rods.

Furthermore, DC motor operates at as a fixed speed for a fixed voltage and there is no slip.

Battery source is used as a power for the motor, low operating voltage is desirable because fewer cells are needed to obtain the specified voltage. However, electronic to drive motor are typically more efficient at higher voltage.

Basically, DC motor is inexpensive, small and comfortable to use and it is controlled by relay circuit.

Relays use an electromagnetic coil to pull the poles of the switch in the position. Most relays returns to the normally closed position by a spring when the coil is energized, so relay contact are usually identified in the same way as those of a momentary contact switch

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Figure-6: Relay circuit

A relay switch can be divided into two parts called input and output. The input section has a coil which generatesa magnetic field when a small voltage from an electronic circuit is applied to it.
This voltage is called the operating voltage. In a basic relay there are threecontacts, normally open (NO), normally close (NC) and common (COM) and coil circuit.
At not input state COM is connected to NC. When the operating voltage is applied the relay coil gets energized and the COM changes contact to NO.
Generally a single pole double throw switch (SPDT). It consists of five terminals. Two coils in which we apply voltage in order to give power to the coils. Polarity is not the matter.
NO is normally open switch where we want the relay to connect the device that we want the relay

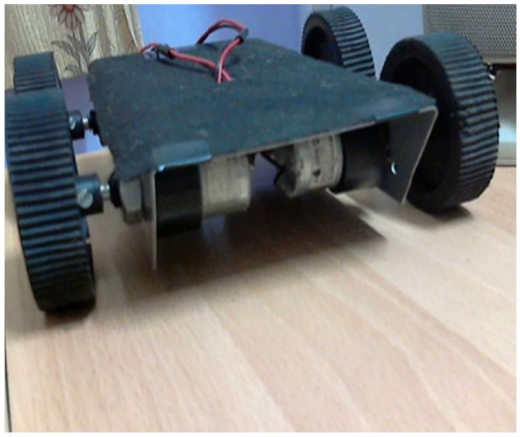


Figure-7: 4 wheel relay circuit

```
#include<lpc21xx.h>
Void delay (into);
Void main ()
{
// P0.6 AND P0.7 FOR LEFT MOTOR
  // P0.8 AND P0.9 FOR RIGHT MOTOR
  //CONSUMES 1.5 SECS

  PINSEL0=0X00000000;
  IODIR0= 0X00000FFF;

// REVERSE BOTH
 // IOSET0= 0X000003C0;
 // Delay (200);
 // IOCLR0 = 0X000003C0;
```

```
 //Delay (200);

            // FORWARD BOTH
  IOSET0= 0X00000140;
Delay (200);
  IOCLR0 = 0X00000140;
Delay (200);
}
```

VIII. ROBOT COMMANDING:

The ARM processor and 4 wheel DC motor operate using universal asynchronous transmission and reception. It uses various commands like DCE and DTE for transmission and reception.
Data communication equipment is usually used for communcating with the different interfacing unit like robotic unit, gsm unit and sensor unit. In our project DCE is used to give the commands to the sensor from the computer.
Simultaneously sensor will give the feedback signal that the observed crack detected signal to the computer so the it enable the GSM through data communication equipment.
Once the message sent to the observer then DTE (date terminal equipment) signal is enabled through the UART port . Mainly the DTE signal is used to establish the new signal or new message to the arm processor.
A signal is transmitted from the DCE unit to the DTE unit simultaneously, it takes around milliseconds to do this action. Both the equipment is grounded to enable the signal transmission.
Both the port are compacted on the signalling unit in the robot kit all auctionsuse AT commands called attention commands. Once the DCE unit is activated, then the attention by both the units.

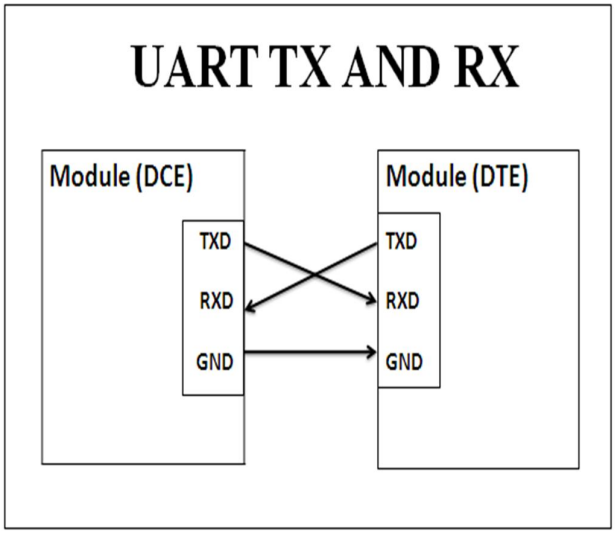


Figure-6: UART TX, RX Operation

DTE such as a microcontroller unit or the external device controller can communicate with the module through its UART port which can be implemented AT command.
The voltage level of UART port interface is 2.8volts. If the voltage of DTE'S UART pin does match with the module, level shifter circuit should be inserted.

IX. UART WORKING

Universal asynchronous receiver and transmitter consist of two different modules like DTE and DCE. Firstly DC transmits the cracked signal using serial that is RS-232 to the microcontroller unit.
Once receiving the signal the data terminal equipment transmits the signal to the global system for mobile communication (GSM).

After receiving the signal GSM will send the stored message to the operator called “crack is detected” and it will reset the signal. Once transmitting the message data terminal equipment will send acknowledged signal to the DCE unit. It takes around milliseconds.

After receiving the signal the DCE will command the 4wheel DC motor to move further and activate the program to detect the crack. All actions are performed in serial port communication using asynchronous reception and transmission.

Usually asynchronous transmission is used because it is simple and doesn’t require synchronization of both communication sides and it is cheap because asynchronous transmission require less hardware and it is faster than other transmission.So that it is suited for application where messages are generated at irregular intervals and its speed depends on different application

In our project UART is as a communication between the DC motor and the sensor unit. The robot is allowed to place in the workplace and its initial position is marked and so the distance of the crack from the initial position can also be calculated.

Global system for mobile communication is used to transfer the message from the robot localization to operate or a controlled room.

Once the crack has been identified by the sensor unit, then it is transferred to the GSM by the UART port and the GSM program were activated by the signal so that the cracked message is sent to the user.

To activate GSM AT commands are used for sending the message.

AT+CMGF=1
OK
AT+CMGS= “9612345678
>“CRACK IS DETECTED”
OK

AT is defined as the attention command in which theCMGF and CMGS commands are used. 1 signifies which mode, we want to activate.

CMGS commands are used to write the message to send to the commander in which the number is defined. Once the number declared the receiver will send the OK button.

It takes around microseconds to retransmit the OK button to the GSM through the UART port signal. This signal will activate the DC motor to move further.

X. ROBOT OPERATION

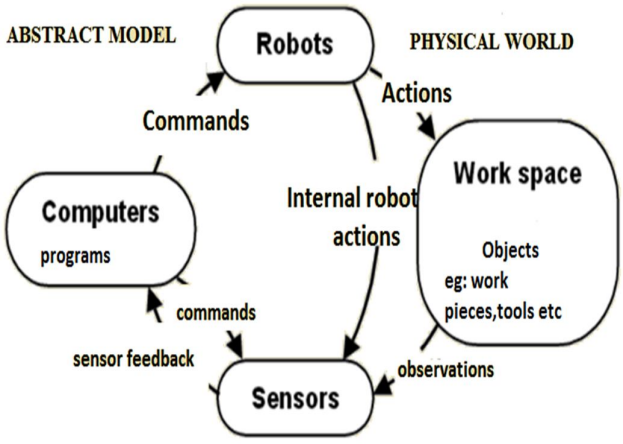


Figure-7: Robot operation in work place

It consists of four different units like sensor unit, computer unit, robotic unit and work place. There are two different models like abstract model and physical model.

Abstract model isa preprocessed system in which the programs are preprocessed and controlled. It consists of a computer. In which the sensor program, robot program is programmed and controlled. A physical model in which real time actions are made like work place and robot actions. The initially robotic unit is allowed to place in a work place it may road or tunnels or bridges in which the robot does the crack detecting actions.Actions are observed by the sensor unit and the feedback is given to the

computer. Computer unit connected to GSM unit.The computer will command the robot. It is a cyclic process.
Meanwhile robot can directly command the sensor unit and computer can also directly command the sensor unit.
All actions are under the control of robotic unit.
Robot consist of the ARM processor, sensor unit and computer programs. Sensor unit consist of infrared and ultrasonic sensor. In which infrared sensor emits the radiation and detect the crack on the work place. Workplace may be roads, bridges, tunnels etc.
The robot is allowed to place in a workplace. It does the actions inthe workplace and sensor unit is activated once the crack is detected it is given to the computer units which consist of GSM unit programs and activate the GSM to send the message as "CRACK IS DETECTED".
After the message sent to the mobile it reset to the original state and make the robot to move forward by UART commands. It consists of ultrasonic sensor by which, if the vehicles crossed the robot or on the position of the robot is identified and takes the other way.
Obstacles in the road are possible so that the ultrasonic sensor is used to detect the obstacles and take the other path. It is useful whether the road consists of more vehicles and traffic.
Initially the robot receives the commands from the computer to do the actions on workplace once receiving the command it activates the sensor unit by internal robot action. The sensor will observe the crack on the work place and send the feedback to the computer that cracks in detected.
After receiving the feedback computer will activate the global system for mobile communication signal to send the crack detected message.
After sending the signal it receives the signal OK from the GSM modem and then commands the sensor internally to sense the crack on work place. Simultaneously, itcommands the robot to move further to detect the crack.
All actions are performed simultaneously and take around milliseconds.The sensoris programmed and four wheel DC motor programs are stored in the computer, so that the manual inspection of the robot is not needed.
It uses certain algorithms to perform the actions,

Step 1:compute command the robotic unit through UART.

Step 2: Robot does the action on roads or bridges etc.

Step 3: sensor observation is made in the sensor unit.

Step 4: sensor feedback is divided into two infrared sensors and ultrasonic sensor.

Step 5: Infrared sensor will detect the crack on workplace and activate the GSM program to send messages.

Step 6: GSM unit sends the "crack is detected"to the operator.

Step 7: ultrasonic sensor will activate the take another path signal to the computer.

Step 8: 4 wheel DC motor will receive the signal and take left or right depends on the command.

Step 9: After sending the message signal computer will reset the sensor.

Step 10: robot can directly activate the sensor unit to do the actions

All the commands are transmitted through the universal asynchronous reception and transmission port. So that it does it wait for synchronization and perform actions in milliseconds.
LPC2148 kit is tiny and portable so that the robot can also hold the circuit throughout the travel to receive the commands.
4 wheel DC motor is controlled by the LPC2148 kit. It is a microcontroller based 32 bit ARM processor with real time emulation and embedded trace support.

XI. IMPLEMENTATION AND RESULT

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A crack detecting robot using sensor was implemented and the crack is detected. It consists of 4 wheels DC motor and the robotic unit along with GSM model.

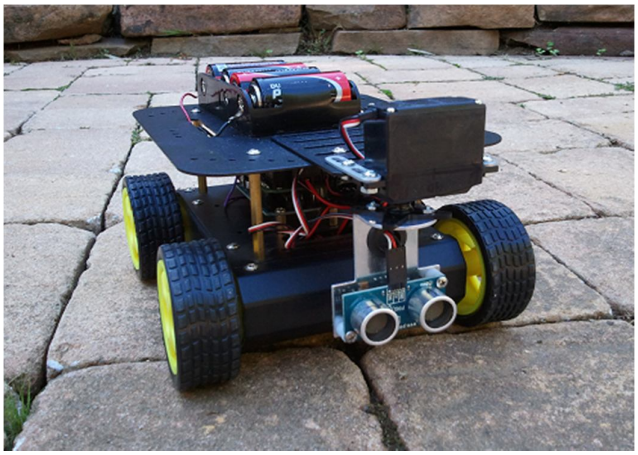


Figure-8: crack detecting robot

12v DC power supply is placed above the robot, it can also be replaced by the sensor unit for power supply to charge. It iscompatible because the arm processor and the sensor unit require less power and utilize the power over a long period.

Infrared and ultrasonic sensor is placed in front of the robot once it detects the crack on superstructure it command the GSM. Ultrasonic sensor which detects the obstacles and take a path by commanding the 4 wheel DC motor.

GSM unit is placed at the center of robot unit once receiving the crack message, itimmediately activates the crack message to the user or a commander.4 wheel DC motor is controlled by the LPC2148 kit. To turn the robot to write the right two motors are kept constant and the left motor is allowed to move further.

Battery support the infrared and ultrasonic sensor. Each battery was found to weigh a little over 300 grams, giving additional weight on the wheels which also ensured the stability of the robot when it moved over road or bridges. These two wooden frameworks were connected by two cylindrical wooden rods (3/4 inch diameter and 0.25 mm thickness).

To move the robot is left direction the left motor is kept constant and the right motor is allowed to move further so that the robot will turn either in the right or left direction. This is unable to cover the entire structure of the roads or bridges.

To traverse a distance of 22 Km in 4 hrs, an average speed of 1.5 meters/seconds is needed. The proposed design uses 4 DC motors (Torque Rating: 10Kg and Speed Rating: 500 RPM)

XII. MECHANICAL DESIGN

The mechanical design of the robot is illustrated in the Figure 8. It consists of 4 wheels connected by the wooden, steel and controlled by the DC motor.DC motor is connected to the arm processor and follows the instructions. The distance and speed given to the robot are user defined and battery power.The sensordetects the crack on super structure and given to the GSM unit it sends the message to the mobile in which it is connected.The operator receives the message like “CRACK IS DETECTED” and the operator resend the OK message to the GSM through the signal.



Figure-9: Crack detected message

Sim card(Airtel) is inserted at the middle portion of the robotic unit so that the message is sent to the operator.The crack was detected exactly at a distance of 200 meters from the start of the course of the robot, which is exactly the distance at which the crack was created.These tests were also conducted in uniform and un-uniform lighting conditions and no false output were detected in either case. The crack detection was also tested for different distances of the created crack with no false output detected.It is not affected by the different lightening conditions. Manual inspection is not needed distance of the crack from the original position is identified and marked.Survey on national highway, bridges crack is detected and checked properly, it works under all lightening conditions

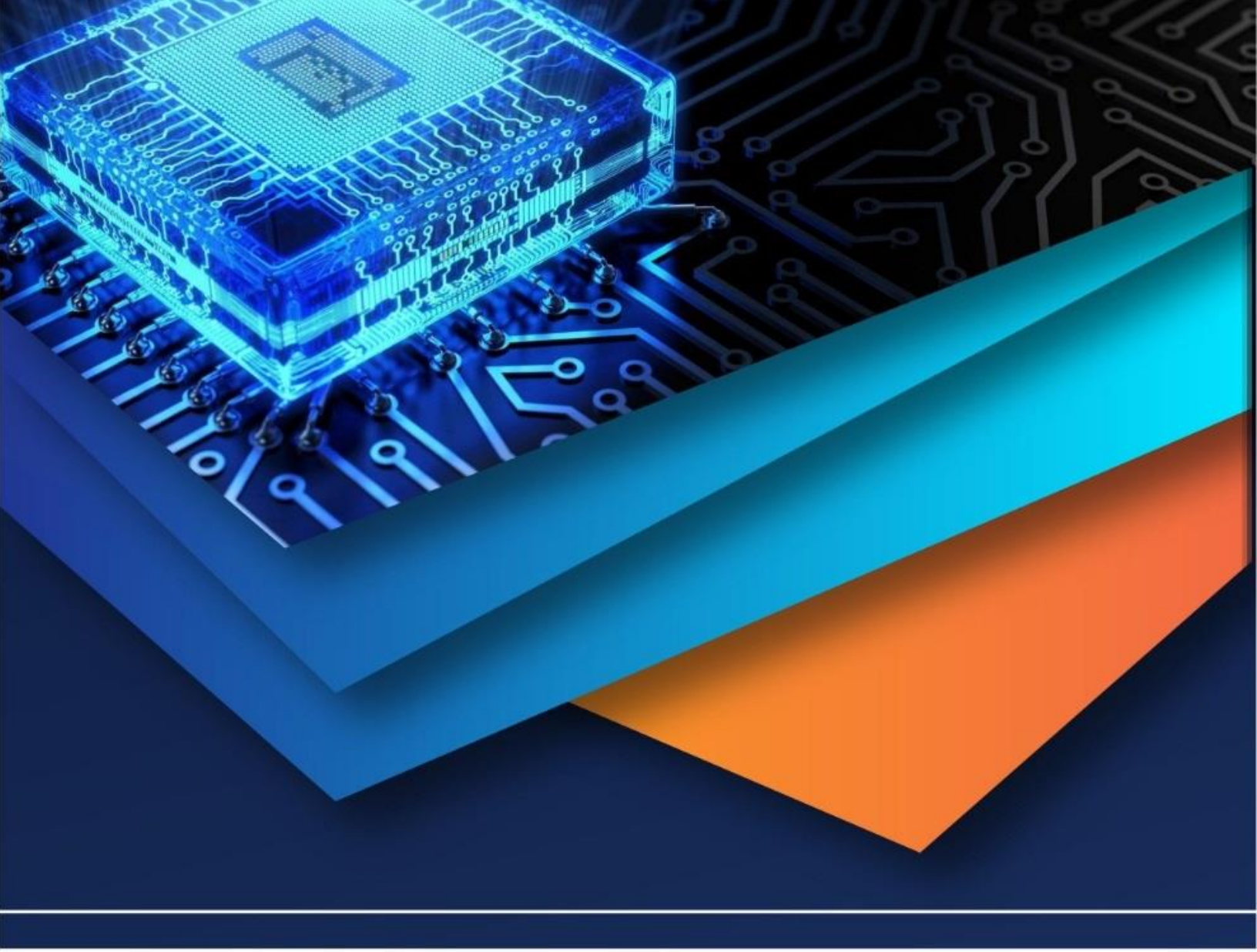
XIII. CONCLUSION AND FUTURE WORK

In this paper, we have proposed infrared and ultrasonic based sensor scheme to detect the crack on super structure such as bridges, roads, tunnels, etc. It can operate in different lightening conditions and produce exact resultsof implementation. It controls the GSM unit to send and receive messages. It uses 12v battery supply to control sensor unit, 4 wheel DC motor and GSM unit so that it is cost effective and produce exact accuracy results. It isa pure sensory based techniqueso that if any defect occurs, it is easy to identify. The presence of crack is detected, but the depth of the crack is not detected in future it can be utilized effectively using sonar. This method is power and battery efficiency, but expensive.

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