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# Robotic Crack Inspection and Mapping System for Bridge Deck Maintenance

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## ABSTRACT

**Crack inspection is a very important work in maintenance of the bridge. There are some artificial and natural aspects such as total no. of vehicles, various loads, dust, humidity, effect of natural light, aging effect, etc. which are responsible causes for structural degradation. It directly implicates that constructive modifications must be done in the bridge structure. Currently inspection is done through a very manual process. An experienced human supervisor monitors the complete bridge surface visually and tries to detect crack on the bridge, but this manual approach is time consuming. Proposed research focuses on implementing a system having a robot equipped with the ultrasonic sensor & GSM module. Cracks will be identified with the help of ultrasonic waves sensor and GSM module to intimate crack depth to the supervisor using simple SMS technology.Robot is also equipped with another electronic device i.e. Cell phone which is having inbuilt HD camera. We discuss how this mobile device can be used as a tool for robotic telecommunication. This methodology of video teleconferencing can be achieved using Skype service app. It can be integrated into an android or windows device to allow a remote user not only to interact with people near the robot, but also to detect minute cracks through visual inspection.**

***Keywords***: Video teleconferencing, Ultrasonic sensor, PIC Microcontroller, Mobile Robot, GSM module.

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## I. INTRODUCTION

One of the greatest challenges engineers face is the inspection, maintenance and safe operation of the existing civil infrastructure. This includes large-scale constructs such as bridges, tunnels, roads and pipelines. Concrete bridges exist throughout India, of various sizes and different forms. They are integral part of highway system even though they are most neglected element of the infrastructure. Safety inspection of concrete structures like bridges is an important factor since it is related to structural health of the structure and provides information whether bridge require maintenance or not. The surface of bridge deck is affected by different weather condition as well as direct load of vehicles so the bridge deck surface is first aspect to be inspected and maintained. Now days it is done through a manual process, an experienced human supervisor monitors the whole bridge surface visually and tries to detect cracks. Since human inspector having limited visual capability, may require repeatability and inconveniency in the inspection. It is dangerous job to supervise the bridge by just passing. So there is a need of designing a system which works with achieving high accuracy. The system proposed will be equipped with a robot, and a cell phone having inbuilt HD camera. It will roam on the bridge surface to collect the real time high resolution video data at predetermined locations. For that we are using video teleconferencing technique of monitoring. Also to determine depth of the cracks combination of ultrasonic sensor & GSM module is used to convey crack depth via text message service to the supervisor, so that the person can take according action on it.

 

## II. EXISTING SYSTEM

**A non-destructive sensing robot for crack detection and deck maintenance. [1]**

Most of the developing countries mainly depend 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 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 crack on the superstructure.
Ultimately, we used Kiel by the 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.

**Design and Implementation of Robotic Crack Inspection for Bridge Deck Maintenance. [2]**

In the existing solution, the robot is equipped with a camera for processing the bridge. It uses histogram evaluation, and fault recognition algorithms for image processing. Thereby, the time taken to inspect the robot will be increasing rapidly. The robot is traversed from start point to end point through an autonomous line following algorithm. Thereby, the data read to navigate the robot is becoming complicated. In the proposed solution, the robot is equipped with a GSM module to intimate the place of cracks/holes occurred to the manager with the simple SMS technology. The robot is also equipped with a RFID Reader to navigate from start point to end point, advanced step of autonomous line following algorithm. The entire bridge was divided into zones; if a crack is occurred in zone1 then a simple SMS is sent to the manager for speedy recovery. The place of identification is not done in the existing solution, but it is done in the proposed solution. Cracks were identified with the help of ultrasonic waves. Sensor Systems were used for identifying the cracks/holes of a bridge. Raspberry Pi is used as a processor for this robot, which is also best alternative used than the existing one. Zone identification is done with the help of slave 8051 controller, processing and intimating the manager is done with the help of Raspberry Pi.

**Skype: a telecommunication framework for robotics. [3]**

This paper describes architecture for robotic telepresence and teleoperation based on the well known tool Skype. We discuss how Skype can be used as a framework for robotic communication and can be integrated into a ROS/Linux framework to allow a remote user to not only interact with people near the robot, but to view maps, sensory data, robot pose and to issue commands to the robot's navigation stack. This allows the remote user to exploit the robot's autonomy, providing a much more convenient navigation interface than simple remote joystick.

**Image Based Detection and Inspection of Cracks on Bridge Surface Using an Autonomous Robot. [4]**

- **Some crack inspection methods with the basic principle.**

| S.N. | Test Method | Principle |
|---|---|---|
| 1 | Ultrasonic Pulse Velocity (UPV) | - Ultrasonic Wave Transmission. - Measurement Of Wave Speed - Frequency-Dependent Attenuation |
| 2 | Ultrasonic Pulse ECHO (UPE) | Transmission and Reflection |
| 3 | Spectral Analysis of Surface Waves (SASW) | Spectral Analysis of Surface Waves |
| 4 | Impact Echo | Transmission and Reflection of Transient Stress Waves |
| 5 | GPR (RADAR) | Transmission and Reflection of Electromagnetic Waves |
| 6 | Percometer | - Measurement of Conductivity and Dielectric Constant - Surface Measurement |
| 7 | Half-cell Potential | Measurement of Electrochemical Potential of Steel in Concrete |
| 8 | Galvanostatic Pulse Method (GPM) | - Polarization properties of Reinforcement -Used In Water Saturated Concrete |

### A. Visual inspection

A conventional and manual approach for bridge deck inspection is human visual inspection which is considered as primary inspection method over other methods and it heavily relies on subjective judgment of inspector. In this method, first entire bridge surface is visually inspected from a close distance, the inspector walk through the surface and try to detect cracks on the bridge and marks the location of cracks. Also this method is carried out using an inspection trolley that travels along surface of bridge which is inconvenient and time consuming. This manual approach having certain limitations such as limited accuracy since human inspector having limited visual capacity and it is dangerous job to inspect the bridge with passing traffic.

 

### B. Image processing based Inspection

Image based bridge inspection originates from known field which we called as signal processing. Image processing includes techniques like image enhancing, image smoothing, edge detection, segmentation etc. Bridge surface images are captured by a high resolution camera as a two dimensional numeric matrix. These numeric matrices are associated with different algorithms which extract information about cracks, non-cracks as well as noise. Different algorithms were designed to enhance image, maximizes contrast level of cracks and minimizes noise level. Image enhancement, histogram thresholding, noise removal and thinning techniques were used in this system.

### C. Radiography method

For cable inspection of bridge radiography technique is used which can detect cable defects using X-rays or gamma rays, X-rays are result of a high voltage X-ray tube whereas gamma rays are produced using radioisotope. Radiography provides two-dimensional tomography for cross-sectional images of three-dimensional objects. Radiography can detect interior flaws such as voids or cracks in cable and cable ducts. It is reliable method. Operational safety is important concern and this method is slow and takes several hours.

### D. Impact-Echo Method

Impact echo is most reliable technique when to inspect relatively small area to detect voids, crack and cavities. By employing this technique crack depth can be determined. In this technique a short duration impact waves are generated onto the test surface. The waves propagate inside the concrete structure and are reflected by opposite face of concrete or when encountered with voids, cracks or cavities. To determined existence and depth of defects, the signals are to be converted into frequency which can be displayed onto screen. Impact echo technique work efficiently in different weather condition and are not influenced by presence of moisture inside concrete. The overview impact echo method and concludes that this method is useful for measuring plate like structure.

## III.BLOCK DIAGRAMS

- **Overall robotic assembly is consist of 2 major systems**

### A. Ultrasonic Crack Detection

In the proposed solution, all components shown in the block diagram are interfaced with PIC 16F87XA. This microcontroller is power efficient. The implementing robot will determine depth of the cracks with the combination of ultrasonic sensor & GSM module. Ultrasonic sensor HC-SR 04 will transmit & receive the sonic waves, and it will convey corresponding distance measured signal to the supervisor via PIC & SIM 900 GSM module. To check the accurate working of the system, LCD display is used. The robot is 12V battery operated. Now for the robotic movement we are using 3DC motors which are quite responsive to the PIC. We can also use Sugar Cube Relays as a substitute for L293D i.e. motor driver IC. Additionally, combination of buzzer and a siren can be use used for alarming the position of the cracks.

All of the blocks required in this system are shown in the fig. below:

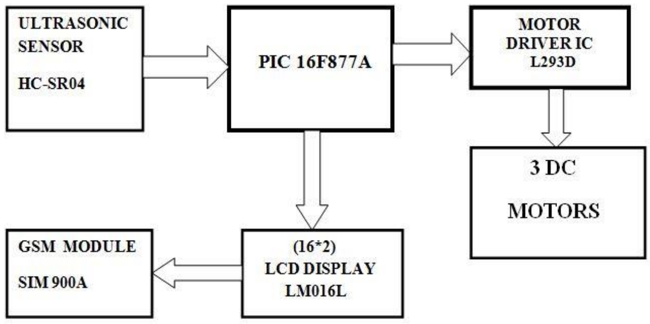


Fig. 1– Assembly block diagram of the robot & ultrasound.

### B. Video telephony with the Skype.

Most people are familiar with the Skype application for teleconferencing. Skype is a voice over IP (VOIP) tool that was created by Niklas Zennstrom and Janus Friis and first released in 2003 as a Windows application. MacOS support came in 2006 and Linux in 2008, and it is also supported a wide range of mobile devices (iOS, Android and Blackberry).Skype has nearly 700 million users and since 2011 is owned by Microsoft. Skype clients use peer-to-peer communications as a distributed database lookup service for call initiation. Super nodes form an overlay network that help connect all Skype clients together and also to the Skype authentications server. Any Skype client outside a firewall will serve as a super node (this can be disabled in modern versions of Skype), and other Skype owned super nodes are dotted around the planet. The Skype login process involves the client authenticating their user name and password with the Skype login server which holds all user names and passwords.The robot is also equipped with high resolution camera cell phone which will transmit real time video data through Skype. Moreover such a live video streaming footage also can be recorded or saved using software for future investigations.

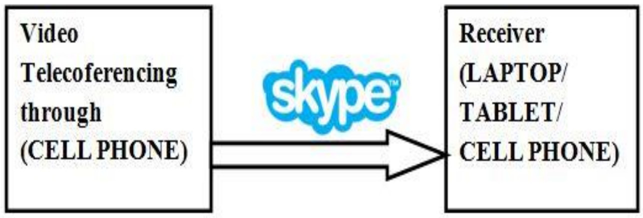


Fig. 2 – Communication between 2 devices.

Google's Hangout, Facebook messenger, Tango are also the best alternative services for continuous HD monitoring & inspection of the cracks.

## IV. HARDWARE DESIGN & COMPONENTS

### A. Ultrasonic Sensor

Ultrasonic Sensor HC-SR04 ultrasonic distance sensor is a popular and low cost solution for non-contact distance measurement function. It can measure distances from 2cm to 400cm with an accuracy of about 3mm. This module includes ultrasonic transmitter, ultrasonic receiver and its control circuit.

1. TRIG and ECHO pins can be used to interface this module with a microcontroller unit.
2. Provide TRIGGER signal, at least 10µS High Level (5V) pulse.
3. The module will automatically transmit eight 40 KHz ultrasonic burst.
4. If there is an obstacle in-front of the module, it will reflect the ultrasonic burst.


Fig. 3- Ultrasonic Sensor

5. If the signal is back, ECHO output of the sensor will be in HIGH state (5V) for duration of time taken for sending and receiving ultrasonic burst.
6. Pulse width ranges from about 150µS to 25mS and if no obstacle is detected, the echo pulse width will be about 38ms

.

### B. PIC 16F8XXA Microcontroller features :

1. CMOS FLASH based 8-bit microcontroller packs is the powerful PIC architecture is available into an 40 or 44 - pin package and is upwards compatible with the PIC16C5X, PIC12CXXX and PIC16C7X devices.
2. 256 bytes of EEPROM data memory,
3. Self programming, Comparators,
4. 8 channels of 10-bit Analog-to-Digital (A/D) converter,
5. 2 capture/compare/PWM functions,
6. a Universal Asynchronous Receiver Transmitter (USART).

All of these features make it ideal for more advanced level A/D applications in automotive, industrial, appliances and consumer applications.

### C. DC Motor

We can't drive a DC Motor **(**depends) directly with a PIC, as DC Motors requires high current and high voltage than a Microcontroller can handle. PIC usually operates at +5 or +3.3V supply and it I/O pin can provide only up to 25mA current. Commonly used DC Motors require 12V supply and 300mA current; moreover interfacing DC Motors directly with PIC may affect the working of Microcontroller due to the Back EMF of the DC Motor. Thus it is clear that, it is not a good idea to interface DC Motor directly with the PIC.


Fig. 4- DC Motor

L293D & sugar cube size relay are two such ICs. Which can be used as dual H-bridge motor drivers, by using one IC we can control two DC Motors in both clock wise and counter clockwise directions. It gives drive currents of up to 600-mA at voltages from 4.5 V to 36 V while L293D can provide up to 1A at same voltages. All inputs of these ICs are TTL compatible and output clamp diodes for inductive transient suppression are also provided internally. These diodes protect our circuit from the Back EMF of DC Motor.

### D. LCD Display

The LCD uses technology called electro-optical modulation. Compatible LCD screens are manufactured in several standard configurations. Common size is one row of eight characters (8x1).We are using LM016L LCD display which is of size 16*2 and this size is readily available as surplus stock for hobbyist and prototyping work.

### E. GSM Module

To intimate the crack depth to the supervisor we are using simple message technology and GSM module i.e. SIM900. It is a complete Quad-band GSM/GPRS solution in a SMT module which can be embedded in the customer applications, featuring an industry standard interface the SIM 850/900/1800/1900 MHz performance for voice, SMS, Data, and Fax in a small form factor and with low power consumption. With a tiny configuration of 24mm x 24mm x 3 mm, SIM900 can fit almost all the space requirements in your M2M application, especially for slim and compact demand of design.

## V. SIMULATION RESULTS

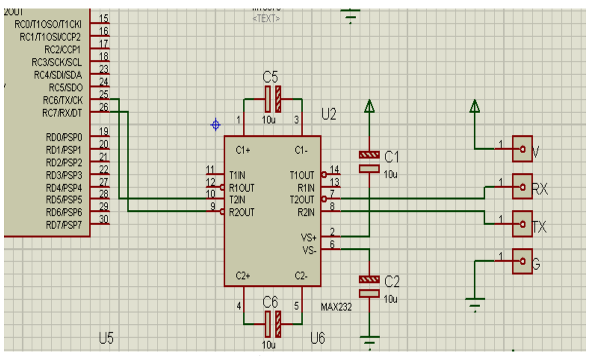


Fig. 5 - Simulation of the PIC with GSM Module.

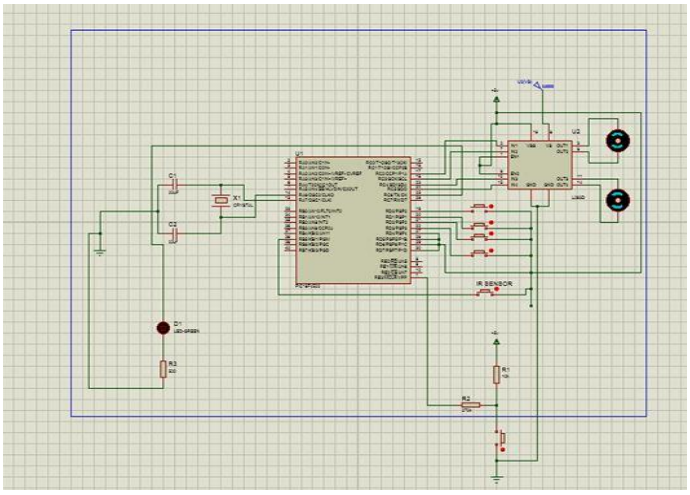

Fig. 6- Circuit Simulation of the PIC with DC Motor.

## VI. SUMMARY

This work proposes Robotic crack detection and mapping system for bridge deck maintenance using mobile robot and is capable of providing the depth size of the cracks. The proposed system consists of mobile robot, a laptop, video teleconferencing / monitoring through Skype, ultrasonic & GSM assembly. All these together provide an efficient system for inspection of bridge surface which enable prevention of the various infrastructure .This system can be further enhanced by using solar panels for automatic and zero maintenance power source. It can also be used for monitoring of the different surfaces.

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