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A Robotic Crack Detection System for Bridge Maintenance

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Abstract: Nowadays, crack detection has become an important necessity for the maintenance of bridge. Earlier, bridges were inspected by a method of human inspection, which had less accuracy in finding out the presence of cracks. So here a system is proposed that uses a robot equipped with a camera that captures images of crack. This images are evaluated using image processing techniques and finally cracks are been identified using edge detection procedures. Mainly canny algorithm is used for the purpose of detecting cracks. When a crack is detected messages are sent to the concerned authority with the help of GSM. This system thus works effectively as a safety system for bridge deck maintenance.

Keywords: Robot, Raspberry Pi, GSM, Image Processing

I. INTRODUCTION

One of the disasters that world witnessed was the collapse of Mississippi Bridge. The incident took away the life of about 13 people and about 100 people were injured during the incident. This accident occurred as a result of lack of maintenance of bridge deck. There is a necessity for the maintenance of bridge decks as they are always prone to damage to chemical exposures. The strength of bridge decks reduces due to the continuous loading and unloading of vehicles. Bridges are normally inspected by human beings. They detect the cracks by simply walking through the bridge surface and thus measure the size and depth of the cracks. The manual approach has several disadvantages:

1 Human error is unavoidable.
2) Accuracy of eyes is different for different people. So accuracy of system depends on the accuracy of the person.
3) Human cannot completely monitor the entire bridge.

Fig 1: Bridge

"An automated inspection system using a mobile robot that detects concrete cracks in a tunnel" Presented by Yu.et.al describes about a system for inspecting and measuring cracks in concrete structures to provide objective crack data to be used in evaluating safety. The disadvantage of the system was the illuminator used in the system for crack detection was not completely stable. A similar paper proposed by Sinha.et.al was "Automated detection of cracks in buried concretes pipe images. The detection of cracks in buried pipes is crucial step in accessing the degree of pipe deterioration for municipal and utility operators. The disadvantage of the system was the images of mushroom crack were not detected well.Lee.et.al proposed a bridge inspection system which consists of a car that control crack.Sohn.et.al developed a system that monitors crack change in concrete structure. The system focuses on quantifying the crack change from multi temporal images. Ito.et.al demonstrated an automated measurement system for concrete block inspection by means of fine crack extraction most of these studies classifies measure and detect crack. However none of these works studies the global mapping of these cracks and the optimization problem in inspection path planning.

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II. ARCHITECTURE OF THE PROPOSED SYSTEM

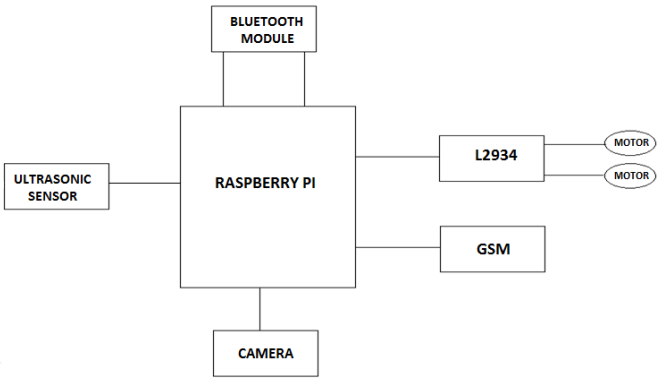

Fig 2: Block Diagram

Component Description: The Raspberry pi module is used as a main controller in the system. All other blocks are connected to this module. Here a Raspberry Pi camera is used which is interfaced with the Raspberry Pi module. The Raspberry Pi camera takes the image of the bridge while the robot is in motion. The robot is controlled with the help of a driver preferably L293D. L293D driver is used to drive the motor of the robot used here. It consist of four input pins, pin 2 and pin 7 on the left and 15 and 10 on the right. Left pins helps in the left side rotation of the motor and the right input causes the right hand side motion. The inputs can be logic 0 or logic 1. But this voltage could not be used for driving the motor. For motor operation, separate supply Vss should be given. The maximum Vss supply is 36V. Maximum current rating is 600 mA.

Conditions for motor operation are:

- Pin 2 = logic 1 and pin7 = logic 0 (clockwise direction)
- Pin 2 = logic 0 and pin7 = logic 1 (anti clockwise direction)
- Pin 2 = logic 0 and pin7 = logic 0 (idle)
- Pin 2 = logic 1 and pin7 = logic 1 (idle)

Similarly, pin 15 and 10 can be regulated for the motor on right hand side to move. The Vcc needed for the operation is 5V. But it could not be used A Bluetooth module is used to control the motion of the mobile robot. Ultrasonic sensor is used to find the depth of the crack detected. A GSM module is used here to send message to the concerned authority explaining about the crack depth. Image processing using canny algorithm is used to detect cracks from the image taken by the camera.

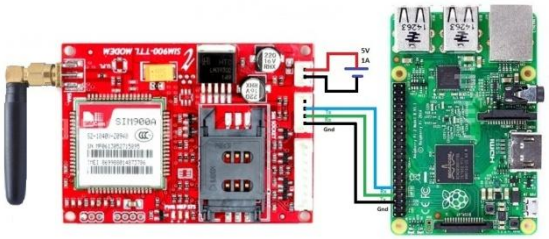

Fig 3: GSM interfacing

MODEL DESCRIPTION: L293D is the driver IC used in the system. It works on the principle of H-bridge. It is 16 pin IC. The two output pins of the IC are connected to the motors used. Two inputs are given by the user who control the robot .Input may be given using a Bluetooth module. Bluetooth module used here is inbuilt in the Raspberry Pi module. It is wireless technology. The Bluetooth module is connected to mobile phone from where we can control the robotic movement. The 1 0 input rotates the robot wheel in clockwise direction and 01 input rotates robot in anticlockwise direction. The working of a mobile robot can be controlled in this way. Raspberry Pi is 40 pin module .It is a high end embedded device. It is credit card sized computer that can be plugged into TV, computer, keyboard etc. Bluetooth, camera, GSM can be connected to different ports in the module. The different ports that we use in this system are:

USB port: mainly used for connecting keyboard, mouse and a wifi adapter

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HDMI port: high Definition Multimedia Interface used to connect TV, monitor, projector.
SD card: An SD card is used here as a storage device.
CSI connector: Camera Serial Interface is used for connecting the Pi camera.
GPIO pins: General Purpose Input and Output pins are used for providing various connections.

GSM system uses digital system such as time division multiplexing. The module working is described as : Sim card is inserted into the GSM module. Wait till the blinking LED comes to a stable state. This tells that the GSM is ready for the working. Working status of the model is indicated by the LED's. Green LED indicates the running of program code. Red LED glows when the system detects a crack. Image processing and edge detection also takes place in the module.

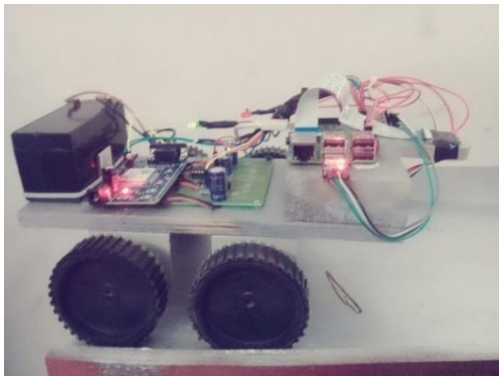

Fig 4: Hardware model

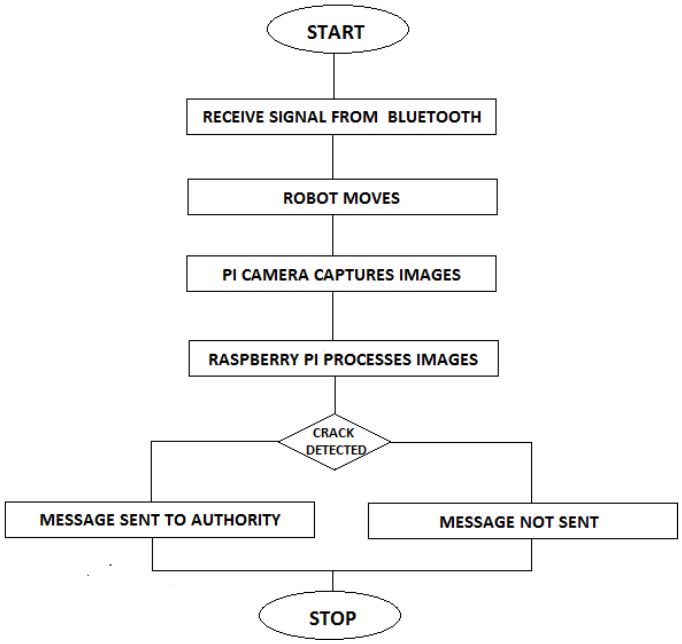

Fig 5: Schematic representation of the system

III. IMAGE DETECTION TECHNIQUE

The image processing technique that sis used in our proposed system is canny edge algorithm. Gaussian filtering is applied for the purpose of removing noise. Here the image is convoluted with the Gaussian filter. The equation for the Gaussian Kernel is:

$$\mathbf{H_{i,j}} = \frac{1}{2\pi\sigma^2} \exp\left(\frac{-(i-(k+1))^2+(j-(k+1))^2}{2\sigma^2}\right) \; ; \; 1 \leq I, j \leq (2k+1) \text{ -(i)}$$

Intensity gradient of the image have been found out. Canny algorithm is applied to the blurred mage for the purpose of vertical, horizontal and diagonal edges. Edge gradient and direction is determined this method.

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$$G = \sqrt{(G_x^2 + G_y^2)}\text{-(ii)}$$

$$\theta = \text{atan2}(G_y, G_x)\text{-(iii)}$$

Next step is the application of non-maximum suppression .The edge that was detected in the previous method is still blurred. So we use non-maximum suppression to get the local maximum values. The pixels that have more edge strength are compared with other pixels and are preserved during the process. After the above process edges become more accurate. This method is used to remove remaining pixels with color variation and noise .For this high and low threshold values are taken. Pixels that are above high threshold value are taken as strong edge pixels .Pixels that are between high and low values are taken as weak edge pixels. Pixel values below low threshold values are suppressed. We so far from the above methods, we have obtained weak and strong pixels. There remains a doubt whether the weak signals belongs to noise or the original image. Weak edge pixels and its eight neighbouring pixels are viewed, using blog analysis and if there is at least one strong pixel in the blog, that weak edge is preserved.

Fig 6: Original image

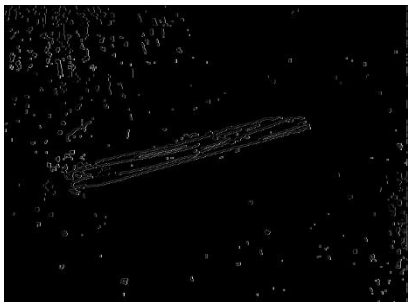

Fig 7:Dialated image

Fig 7:Image as edge detected

Fig 8:Final edge detected image

Canny algorithm has the following parameters:

1) The size of the Gaussian filter that is being used in the system .
2) The size of the smoothening filter used.
3) Threshold: It should be more flexible but there arises a disadvantage that if the threshold value is high it can cause the loss of information, thereby reducing the efficiency of filtering.

IV. RESULT AND OBSERVATION

According to the experiments conducted using the system, the height, width and depth of the crack can be calculated. The results were proven successful and observations are as follows:

Table 1**:** Observation of crack

SL.NO	HEIGHT	WIDTH	DEPTH
1	359	148	4
2	398	187	3
3	352	157	4

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Robot was allowed to move through the bridge. The pi camera in the module captures the continuous image that is present on the bridge deck and this is further given to the Raspberry pi module and if crack is detected using canny edge detection algorithm and the message is sent to the concerned authority through the GSM module in the order of height, width and depth.

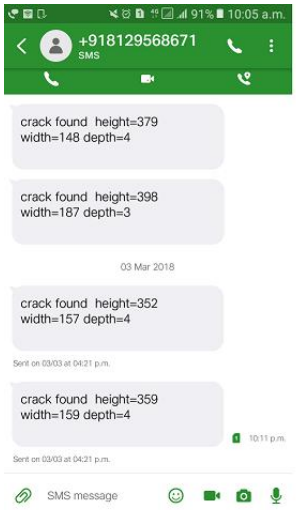

Fig 9: Message sent to authority

V. CONCLUSION

The proposed system provides overall solution to bridge deck crack detection. The system reduce risk for humans increases the accuracy. The system is less expensive and provides a good solution to the crack detection problems in developing countries. Our proposed system uses canny algorithm to collect images effectively in all areas and GSM module for sending the data to the concerned authority. The proposed system is useful in development of the quality of bridge decks.it also provides safety assurance. This system can even be improved by the use of RF transmitter and receiver .this provides a more efficient method for bridge maintenance .The system can be easily implemented with reduced cost.

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