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

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Abstract - Crack inspection is an important task in the maintenance of bridge and it is closely related to structural health of bridge. Currently it is done through a very manual procedure, an experienced human inspector monitors the whole bridge surface visually and try to detect cracks on the bridge and marks the location of crack. But this manual approach having some limitations such limited accuracy. Proposed research focuses on implementing a system having a robot, equipped with a camera to collect images of surface and a global map is created locating position of cracks. The robot will navigate on the bridge surface to collect the surface image data at predetermined locations. An image processing technique is used for processing the image and creating map of cracks. We will use different algorithm in image processing which can find out the cracks and non-cracks in an image. In this research we will create 2D-map which is essential and main aim of this work.

Keyword: *crack inspection, global map, image processing.*

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I. INTRODUCTION

Timely inspection and maintenance of civil, mechanical and aerospace structures can prevent minor deficiencies, which can cause catastrophic disasters. Concrete bridges exist throughout the 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 structure and provides information whether bridge require maintenance or not. About forty years ago, technology was not enough advanced and manual approach were adopted. Safety was not important concern as today. Current bridge inspection and maintenance have resulted in response to catastrophic disaster; with each disaster new facts were evolved and protocols were implemented hence different methods were presented for bridge inspection. According to the National Bridge inspection standards, if a bridge is 20 ft long, is to be inspected at least once every 12 month, can reduce risk of catastrophic failure. Different studies have shown that regular and periodic inspection and maintenance is a cost effective investment.

The surface of Bridge deck is affected by different environmental condition as well as direct load of vehicles so the bridge deck surface is first component to be inspected and maintained. The owners of these bridges whether be a local or state government, always look for the cost effective means for inspection and maintenance. Safe operations are demanded, protection of workers safety and health as both moral obligation. Inspecting and correcting minor deficiencies like cracks while the structure still in good condition will ensure the structural reliability and small repairs, activities will be performed to keep the bridge in good condition and thereby avoid large expenses in major rehabilitation or replacement.

Currently it is done through a very manual procedure, an experienced human inspector monitors the whole bridge surface visually and try to detect cracks on the bridge and marks the location of crack, but this manual approach having some limitations. Such as limited accuracy since human inspector having limited visual capability may require repeatability due to variability and inconsistencies in inspection. It is dangerous job to inspect the bridge with passing traffic also these inspections become too laborious and slow. So there is a need of designing a system which works with achieving high accuracy. The system proposed will be equipped with a robot, a high resolution camera to collect images of surface and a global map is created locating position of cracks. The robot will navigate on the bridge surface to collect the surface image data at predetermined locations. An image processing technique will be used for processing the image.

II. LITRATURE SURVEY

In this section we review various studies and development carried out by many researchers. We will also see existing robotics and localization based studies.

Sung-yul An, Jae-ho Jang, Chang-soo Han, and Pyung-hwa Kim [1] has presented an automated inspection system using a mobile robot that can detect concrete cracks in a tunnel employing an illuminator. In their system cracks are inspected vertically and horizontally. The mobile robot system consists of a CCD camera that can capture images of concrete structure and maximizes contrast distribution of cracks and non cracks. The camera usually require high power illuminator, a maximum of 1000 W halogen light is used. The numerical information of cracks are extracted and computed by crack detecting system which utilizes software. To ensure that camera captures fine images mobile robot has to maintain a constant distance from the structure therefore a laser sensor is used to obtain distance from structure. This system was limited by complete use of the automation in an unpredictable environment hence semi-automatic algorithm is realized. To extract information of crack, the edge of the crack was

extracted and 'Laplacian' as well as 'Sobel' operator were applied. To obtain orientation of edge the Sobel operator is used. Dijkstra method was utilizes to find out shortest path. This system was experimented and tested in the indoor structures, road tunnel and subway tunnel.

Xu Xue-jun, Zhang Xiaoning [2] has developed a system to detect cracks in the concrete bridge using video images. Visual C++6.0 was used to develop a computer program which can detect cracks efficiently. This system consists of three parts.

(a) Bridge video images
(b) Image processing Techniques
(c) Crack identification algorithms

Firstly, some grid check-boards were fixed on the surface of bridge/beam then a high resolution digital camera is used to shoot video data. This video data is send to computer server using a designated network. Once the computer server receives the video data, image processing techniques were applied. Since video data is of color images they are converted into grey scale images then techniques like grey image processing, image noise filter and calculating pixel rate were applied. Optimization of grey scale image can enhance distribution of pixel value. For optimization of grey scale images two methods were used namely linear stretching and Histogram equalization. For the pixel rate, computer program identifies the corners and calculates distance of any two corners in check-board. Finally, the crack identification algorithm was used which identifies crack and extract features like perimeter, area and width.

Ronny Salim Lim, Hung Manh La and Weihua Sheng [3] proposed a robotic crack inspection and mapping system. this system consist of a mobile robot which sends images of bridge using canon VC50i camera having resolution of 860x640 and having zooming factor of 26, to the laptop which is wirelessly connected to mobile robot. Before inspection of bridge, a two-dimensional bridge deck map was created such that robot can localize itself when capturing images. For this purpose simultaneous localization and mapping algorithm is used which estimates the location of robot and at the same time give two-dimensional map. Mapper3 software is used for this purpose. After this robot was localize based on algorithm which is called as Monte Carlo localization algorithm [10].

Image-global coordinate system transformation was derived to develop crack map which is multiplication of Robot-global, camera-robot, image-camera coordinate transformation. Laplacian of Gaussian algorithm processes all the images in order to detect cracks. They have defined path planning statement such that mobile robot captures all the images of surface efficiently. This path planning was defined by using an algorithm which is called RIP-GA or genetic algorithm. The output of this RIP-GA algorithm is a path having a pattern, which includes different camera posses, location of robot, number of turns that robot moves etc. this RIP-GA algorithm minimizes the no of turns as well as minimizes travelling distance. After this camera motion and robot motion were set. Finally when all the images are collected and sent to the laptop, image processing techniques were applied to find out the cracks. For crack detection MATLAB software was used. The main idea behind crack was to find out edge points in the image. By finding out zero crossing of second derivative of image intensity, the edge points were found. Noise was filtered out by using Laplacian of Gaussian algorithm.

A global crack map was created showing the exact location of cracks. This system was experimented in the different type environment and surfaces as well.

Recently various works are carried in crack detection using neural network and fuzzy logic model.

Fuzzy logic and image processing based approach was proposed by Gajanan K. Choudhary and Sayan Dey [4]. Image processing technique was used to extract the feature of an image. By using edge detection technique, resizing, grayscale conversion of color image, morphologic operation were performed on the image. They have presented two approach to handle crack detection namely image approach and object approach. In the image approach, area and ratio of all objects feed into Neural network Model as input and output were '1' and '0'. '1' means image having at least one crack and '0' means image is crack free. The second approach was object approach, in which fuzzy logic model and another set of Neural network model was used. Various parameters were used to feed into these models. Object approach distinguishes each component of image into cracks and non-cracks. This model was tested over 205 images and concluded that object approach is better than image approach.

Similar approach was proposed by Hyeong-Gyeong Moon and Jung-Hoon Kim [5] using neural network. This system was automatic crack detection and algorithm was divided into two parts; crack detection and classification. Again in image processing cracks are distinguishes by filtering, the subtraction method and morphological operation. Various parameters are extracted such as ratio of major to minor axis, pixel rate etc. The image classification uses neural network model to identify existence of crack. The crack recognition rate was 90% whereas non-crack recognition rate was 92%. This system was useful for non-expert inspectors. Sylvie CHAMBON [6] detected cracks using multiple images using different sensors and based on wavelet decomposition analysis.

Sinha and Paul W. Fieguth [7] proposed detection of cracks in underground pipeline and used image processing techniques. Wei Xu [8] detected pavement cracks using statical features. Road cracks was detected and inspected by Miguel [9] using SVM based approach.

Since the automatic robot crack detection system uses localization algorithms, [3] have adopted monte carlo algorithm. Amitangshu [10] overviewed and presented existing approaches of localization algorithms. He classified localization as; Centralized and Distributed localization algorithm. Following is tree diagram of all algorithms.

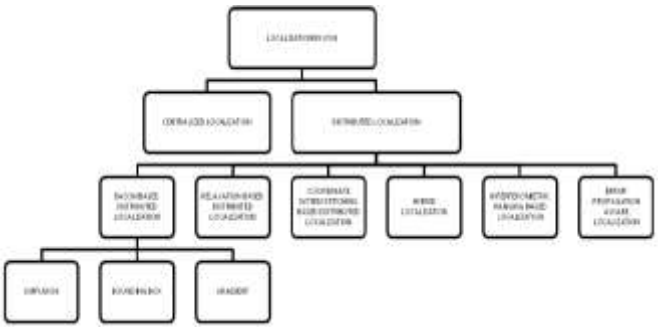

Figure1. Localization Algorithms

III. BRIDGE INSPECTION METHODS

In this section, we will see bridge inspection methods and Non-Destructive testing (NDT) for surface of bridge deck as well as cable inspection method.

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. This method is also used for cable inspection of bridge.

B. Image processing based Inspection

Image processing is an active research area. 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. These numeric matrices are processed by different image processing techniques. Different algorithms were designed to enhance image, maximizes contrast level of cracks and minimizes noise level. Hong-Gyoo Sohn [12] uses image processing techniques to develop crack monitoring system for concrete structure. Image enhancement, histogram thresholding, noise removal and thinning techniques were used in this system.

C. Ultrasonic crack inspection

One of the widely used methods for bridge inspection is ultrasonic inspection which can detect the presence of defects or cracks in the concrete structures. This method can also be used for cable inspection of bridges. An ultrasonic device consists of a 'Transmitter' which can send high frequency sound wave and reflected signals are received by a 'Receiver '. An acoustic emission technique is used which can find out presence of defect or crack in the structure. Structural defects as a discontinuity reflect the transmitted signal to receiver as a sign of presence of defects. For transmission, long guided waves are used as a transmitting signal. The size and location of defects and cracks can be computed by magnitude as well as delay time of reflected signal. The ultrasonic test results are subjective to the inspectors experience and judgment as well as proper handling of device.

Musolino [13] investigated feasibility of NDT method for concrete structure using ultrasonic wave propagation. Characteristics of reflected waves were analyzed to locate defect.

D. 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 but having certain limitation since the fact that radiographic technique are complicated, operational safety is important concern and this method is slow and takes several hours.

E. 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. Carino [14] overview impact echo method and concludes that this method is useful for measuring plate like structure.

Following are some NDT methods with their basic principle.

Table 1. NDT methods for crack detection and principles.

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

IV. PROPOSED SYSTEM

From the above studies we can propose automatic crack detection and mapping system which is capable of taking images, detects crack and provides a global crack map of bridge surface. Crack detection techniques require advancement, the system we develop will consist of mobile robot which will moves on the bridge surface, and we inspect half of bridge at a time while shifting traffic to other half. In this system we try to send images wirelessly to the laptop, where images will be processed through image processing techniques, we can employee edge detection techniques for crack detection and bounding box algorithm for localization of robot.

The entire project will be divided into following three modules.

A. Designing of Robot and Programming the Hardware

In this module we will select the different hardware component like microcontroller, a high resolution camera, Rf module which can transmit captured images. Secondly Eagle software will be used for schematic creation & layout generation. After this we will be developing the algorithm for crack detection, path planning of robot and then program the microcontroller by the programmer. We will try to establish a wireless connection between the laptop and robot .We can also save the images to memory card.

B. Image processing on MATLAB

The images captured by robot are transmitted to the laptop/PC for image processing. Image processing is done in MATLAB software. Any image contains extra irrelevant information which needs to be removed by preprocessing to facilitate the process of crack detection by making it more efficient and time saving. We can employ the different techniques for image processing such as resizing the image, conversion of color image into grayscale, superimposing grayscale image with the original image, morphological operations etc. We will use different algorithm in image processing which can find out the edges in an image also we will implement such algorithm and techniques which can distinguish between cracks and non-crack. In this module we will create 2D-map which is essential and main aim of this work.

C. Testing

In this module we will test the system for different types of surfaces and structures like concrete surface, metal surface, wooden surface even we will try to detect the cracks in pipeline of large size. Different lightning conditions and shadow images will be tested through the image processing to further enhance this system.

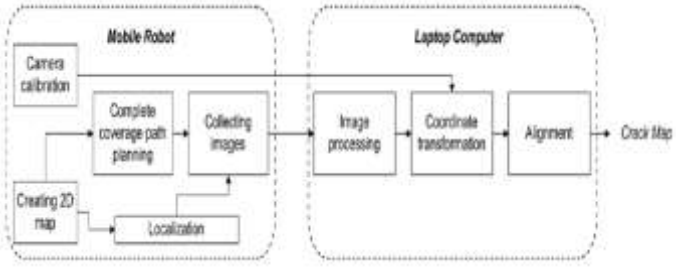

Figure2. Proposed System

V. CONCLUSION

This work proposes crack detection and mapping system for bridge surface using mobile robot and is capable of providing a global crack map locating cracks. The proposed system consists of mobile robot, a laptop, image processing algorithm and software's. All these together provide an efficient system for inspection of bridge surface which enable prevention of catastrophic consequences thereby avoid large expenses in major rehabilitation or replacement. This system can be further enhanced and can be used for different surfaces as well.

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