COST EFFECTIVE AUTOMATED CRACK DETECTION SCHEME BY USING A MOBILE ROBOT

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Abstract - *Different engineering structures like bridges, beams, concrete structures, etc are subjected to different problems due to the improper construction method adopted and carelessness during initial construction. They are also often subjected to fatigue stress, cyclic loading and other environmental changes, which creates breaks on the structures called cracks that results in the reduction of stiffness in the structure as well as creates deformities in the structure. Thus, it is necessary to detect and take preventive measures against cracks in order to prevent further damage and possible failures of the structures in order to avoid accidents and for easy maintenance and there requires the need of automated crack detection scheme. The proposed system consists of a robot, a high resolution camera to collect images of surfaces and a global map for locating the position of cracks. The robot will navigate on the surface of the structure like bridges to collect the surface image data at predetermined locations. An image processing technique is also used for processing the image.*

Index Terms **- Cracks, Automated crack detection, Robot, Image processing technique, Morphology.**

I. INTRODUCTION

Bridges are also the subways which are considered as one of the way to reduce the traffic issues created in the cities. But due to fatigue stress, cyclic loading, aging, thermal expansion and contraction, environmental changes, human damages etc. these bridges are affected by small breaks in their inner and outer surfaces. These breaks are usually called cracks that will directly or indirectly will affect the health status of the bridges. Thus, regular monitoring about cracks in the bridges is necessary in order to avoid the damages in the bridges that results in accidents.

Protections of bridges are mainly handled by state or local government. They will mainly adopt cost effective methods for the purpose of detection of cracks and maintenance of bridges. Detecting the cracks in the bridges and rectifying the cracks at the earliest stages will ensure the reliability in the structure and thus to keep the bridges in the good condition and hence it is able avoid the large expenses for the purpose of maintenance.

In the past years, detection of cracks on the bridges is done manually, by an experienced human inspector who will monitor the whole bridge surface, tries to detect the cracks and locates the cracks. This manual procedure of detecting the cracks on the bridges have some limitations such as detection rate, detection

efficiency and detection accuracy. It is also very dangerous to detect the cracks on bridges with passing traffic that makes labors work tedious and slow.

Due to the advancement in computer imaging and image processing techniques automated crack detection procedure is adopted by replacing the manual procedure for crack detection and more accurate information regarding the cracks can also be estimated. Crack detection filters of different sizes had been designed in order to identify the cracked regions from the detected images of cracks. Charged Couple Device (CCD) cameras and a mobile robot system were built to acquire the image data are used for detecting the cracks in a tunnel.

There are edge detection algorithms as well as transform and statistical band methods were applied for the assessment of cracks in the structures. Texture analysis approach was one of the most efficient methods for extracting the images of cracks from the acoustic imagery. There are also other statistical texture analysis methods for the purpose of crack detection with increased accuracy rate. A novel computer vision method is also adopted for the crack detection with the more increased accuracy rate. There are Charged Couple Device (CCD) cameras developed based on computer vision technique for the purpose of crack detection.

Instead of slower manual detection of cracks, automatic crack detection scheme is developed for the fast and reliable crack detection. Crack detection can be done in two ways such as Destructive testing and Non destructive testing. Non destructive testing is more effective for automated crack detection which can be done by using laser testing, radiographic testing, ultrasonic testing, infrared testing, thermal testing etc.

Disadvantages of manual crack detection also includes trouble to monitor all the elements in the large structure, safety issues to inspectors who take cracked images and also it is difficult for the revision of cracked images according to camera angle. Thus, image based analysis of crack detection based on image processing techniques has been developed which provides more accurate results than conventional crack detection schemes. A high resolution camera is used for the collection of detailed images of cracked surfaces detected. Due to difficulties in the image based detection scheme different image processing techniques were proposed based on certain criteria's and parameters of the detected image of cracks.

Thus, there is a need for implementing a cost effective automated crack detection scheme on bridges that works with high accuracy. Due to the advancement of the proposed automated crack detection scheme on bridges, it is capable to detect the cracks, takes the images and to provide the global crack map of the bridge surface. The system consists of a mobile robot which will moves on the bridge surface and thus inspects half of the bridge at a time, while shifting the traffic to the other half. Images are sent by using any of the wireless method to the laptop where the images are processed through image processing techniques. Here edge detection technique is used for crack detection and bounding box algorithm for the localization of the robot.

II. LITERATURE REVIEW

Manual method is one of the methods for the crack detection and estimation. In the manual inspection method sketches are prepared manually for the detected images and all the irregularities are noted. In this

approach of crack detection there requires the objectivity in the quantitative analysis of the surface images is essential. So, automatic image based crack detection scheme is employed as a replacement for the manual procedure of crack detection. Accordingly, different papers are taken then revised. Review analysis is done based on the various crack detection scheme and methods based on the various parameters used.

Automated Crack Detection on Concrete Bridges [1] Detection of cracks on bridge desk is a vital task for maintaining the structural health and reliability of concrete bridges. Robotic imaging can be used to obtain the bridge surface image sets for automated on-site analysis. Here a novel automated crack detection algorithm, the STRUM (Spatially Tuned Robust Multi Feature) classifier and demonstrate the results on real bridge data using a state of the art at robotic bridge scanning system. The algorithm uses robust curve fitting to spatially localize potential cracks regions even the presence of noise. Multiple visual features that are spatially tuned to these regions are computed. In order to create a composite global view of a large bridge span, an image sequence from the robot is aligned computationally to create a continuous mosaic. A crack density map for the bridge mosaic provides a computational description as well as a global view of the spatial patterns of bridge deck cracking. The automated crack detection algorithm can analyze an image sequence with full view coverage of the region of the interest at high resolution. The image sequence can be acquired with a robotic measurement device with attached cameras or with a mobile cart equipped with the surface imaging cameras.

Automatic Crack Detection and Classification Method for Subway Tunnel Safety Monitoring [2] With the application of high speed Complementary Metal Oxide Semiconductor (CMOS), industrial cameras, the tunnel surfaces can be captured and stored in digital images. In a next step, the local dark regions with potential crack defects are segmented from the original gray scale images by utilizing the morphological image processing technique and thresholding operation. In the feature extraction process, a distance histogram based shape descriptor that effectively describes the spatial shape difference between cracks and other irrelevant objects are presented. The original tunnel images are collected by CMOS line scan cameras. These color images are transferred into gray scale images for further processing. In order to distinguish between the cracks and unexpected irrelevant objects, feature extraction becomes the key problem to be solved. Thus a shape descriptor called a distance histogram is proposed to perceive the difference between cracks and irregular objects. Along with the standard deviation of the distance histogram two additional numerical features are used for the basis for classifying the cracks. With the pattern recognition algorithm or a thresholding classification operation, unexpected objects will be removed and cracks will remain.

Auto Inspection System Using a Mobile Robot for Detecting Concrete Cracks in a Tunnel [3] An Automated inspection system using a mobile robot that can detect the concrete cracks in a tunnel employing an illuminator. In this system, cracks are inspected horizontally and vertically. The mobile robot system consists of Charged Coupled Device (CCD) cameras that can capture images of concrete structures and maximizes the contrast distribution of cracks. The cameras usually requires high power illuminator, a maximum of 1000w halogen light is used. The numerical information of cracks are extracted and computed by crack detection system which utilizes the software. To ensure that the 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 the structure. This system can limited by complete use of

automation in an unpredictable environment. Hence semi automatic algorithm is realized. To extract the information of cracks, the edge of the cracks was extracted and Laplacian as used a Sobel operator was applied to obtain the orientation of edge.

Application of Computer Vision to Crack Detection of Concrete Structure [4] At present, several inspection systems coupled with Charge Coupled Devices (CCD) cameras have been developed and applied to infrastructure inspections inorder to reduce the danger of accidents to the human inspector. A novel computer vision method adopted is based on a computer vision technique based as CCD images to attempt to automatically detect the cracks in a concrete structures. As per the computer vision method, in which weighted median filter, image opening, Otsu's thresholding and measurement of morphological features are executed, to automatically detect cracks in the concrete structures. The morphological features including area and eccentricity were measured for each segmented image region. Based on the measured morphological features, a sensitivity analysis was applied to establish several criteria for crack detection which are more effective.

Intelligent Crack Detection Algorithm on the Concrete Crack Image using Neural Network [5] An Automatic crack detection System is employed that can analyze the concrete surface and visualize the cracks efficiently. Algorithm is used which consists of two parts, image processing and image classification. In the first step, cracks are distinguished from background image easily using the filtering, the improved subtraction method and the morphological operation. The particular data such as the number of pixel and the ratio of major to minor axis for connected pixels are also extracted. In the second step, the existences of cracks are identified. Back propagation neural network is used to automate the image classification. Target data values in the training process were generated by the manual classification of inspector. This method is useful for non expert inspector, enabling them to perform crack monitoring tasks effectively.

A Robotic Crack Inspection and Mapping System for Bridge Deck Maintenance [6] The system proposes a robotic crack inspection and mapping system consists of a mobile robot which sends images of bridges using canon VC50i camera having high resolution of 860x640 and having a zooming factor of 26, to the laptop which is wirelessly connected to the mobile robot. Before inspection of bridges 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 the two dimensional map.

Unmanned Aerial Vehicle (UAV) Powered Concrete Detection Based on Digital Image Processing [7] Recent advances in UAV technologies are considered as a prominent tool to monitor the crack detection. In particular the UAV associated with the sensing capability and computer vision can be innovative approach for large scale infrastructure monitoring. To calculate the crack widths, the UAV based systems is essentially needed to take crack images and associated distance information. Digital Image Processing has been introduced as an alternative automatic crack assessment to the visual inspection. Here UAV technology is adopted along with the image processing. The proposed UAV is equipped with Raspberry Pi, camera and ultrasonic displacement sensor which can measure the crack image and distance information while UAV is flying. The used image processing strategies are subtraction with median filter,

Sauvola's binarization method, image revision using eccentricity and connection of pixels and crack decomposition and width calculation algorithm.

Crack Detection on Concrete Surfaces using Image Processing, Fuzzy Logic, and Neural Networks [8] Image processing technique was used to extract the feature of an image. By using the edge detection technique, resizing, gay scale, conversion of color image, morphological operations were performed on the image. There are mainly two approaches to handle the crack detection such as image approach and object approach. In the image approach, area and ratio of all objects feed into neural network module as input and output were '1' and '0'. '1' means images having at least one crack and '0' means images are crack neural network model was used. Various parameters were used to feed to these models. Object approach distinguishes each component of image into cracks and non cracks which are more efficient method.

Detection Crack in Image Using Otsu Method and Multiple Filtering in Image Processing Technique [9] A new approach is presented in which an image processing technique has been used for detecting the cracks on images. There are mainly three steps for the methodology involved. Firstly, change the image to a gray image using the edge of the image and then use Sobel's method to develop an image using Sobel's filter for detecting cracks. Then by using suitable threshold binary image of the pixel they are categorized into the foreground and the background image. Once the images are categorized Sobel's filtering was used for the elimination of residual noise. After the vast filtering procedure of the image, cracks were detected using the Otsu's method. They have replaced the Sobel's filter with the multiple median filtering in certain cases.

Crack Detector Robot Using LED – LDR [10] Rail transport plays a vital role and it is one of the cheapest mode of transportation in India. One of the main problems associated is cracks in the railway track. The crack detection scheme consists of Light Emitting Diode (LED) and Light Dependent Resistor (LDR) assembly that functions as the rail crack detector. Principle involved in the crack detection is very simple. To communicate the received information a GSM modem has been utilized. Exact location of the crack in rails is located by the GPS receiver. There are also chances for false crack detection, hence a concept called dead band is introduced. The dead band concept reveals that when the threshold value is set for crack detection that is only when the generated output is greater than the threshold value, there is a crack. Once the crack was identified the robot will get stopped so that the crack location is found accurately. Then by using the GPS receiver information are send to the corresponding mobile number using GSM module.

III. SYSTEM MODEL

Crack detection on structures such as bridges, high rising towers, dams etc is very important. But there are some limitations on the crack detection for these structures regarding the geometry and spatial constraints of the structure. It is necessary to maintain the structural health and reliability of the structure for the future purposes. Hence, continuous assessment of the structures is necessary.

The proposed system is cost effective method for the crack detection on the structures and it is an effective solution to the problem of crack detection on the structures such as bridges, dams etc. Crack

detection techniques requires advancement than the manual procedure for the exact detection accuracy, detection efficiency and detection rate.

There are mainly three modules for the proposed crack detecting scheme such as

1. Robotic Unit
2. Programming Hardware Unit
3. Image Processing Unit

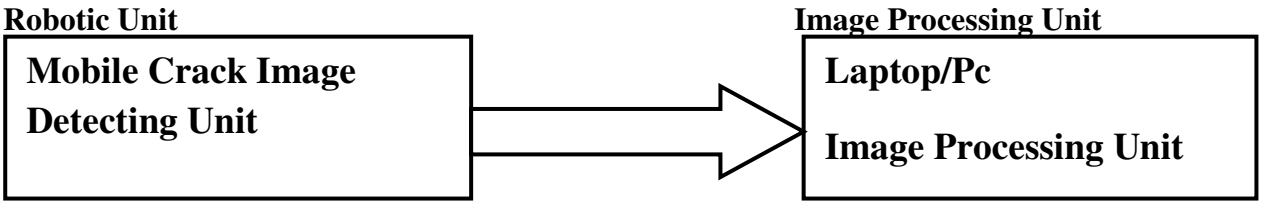

Figure 1: Proposed System

Robotic Unit consists of a mobile robot that will move on the bridge surface inorder to detect the cracks on the structures. The main heart of programming the hardware unit is microcontroller. A high resolution camera has been used inorder to collect images of surfaces. A global map is also created for locating the position of cracks that can transmit the captured images. By using the wireless method like Bluetooth; images are sent to the laptop where images are processed through image processing techniques. Thus, a wireless connection has been established between the robotic unit and laptop. An algorithm is developed for crack detection, path planning of robot and then program the microcontroller by the programmer. Once the crack has been detected successfully and images are sent along with the location, the mobile robot moves further on the model path till next crack has been detected.

IV. BLOCK DIAGRAM OF PROPOSED SYSTEM

The following figure shows the block diagram of the proposed crack detection system which consists of microcontroller unit that controls all the signals and various control units in the system. The overall function in this system proposed can be controlled with the help of ATMEGA328 microcontroller.

The main function of the robotic unit is controlled by the microcontroller ATMEGA328 which performs the particular task depending upon the predetermined programs employed. Bluetooth is used to exchange the data from the robotic unit to the microcontroller. A high pixel IP camera module or Internet Protocol camera has been employed for the purpose of sending and receiving the image data via a computer network and the internet.

The microcontroller unit which forms the heart of the proposed system consists of a motor driving unit and alert unit. There are motors with motor drivers that is used to drive the motors. Motor drivers will act as a current amplifier since it takes a low current control signal and then turns it into a higher current signal that can drive a motor. Alert unit consists of alarm and LED inorder to indicate the presence of cracks on the surfaces.

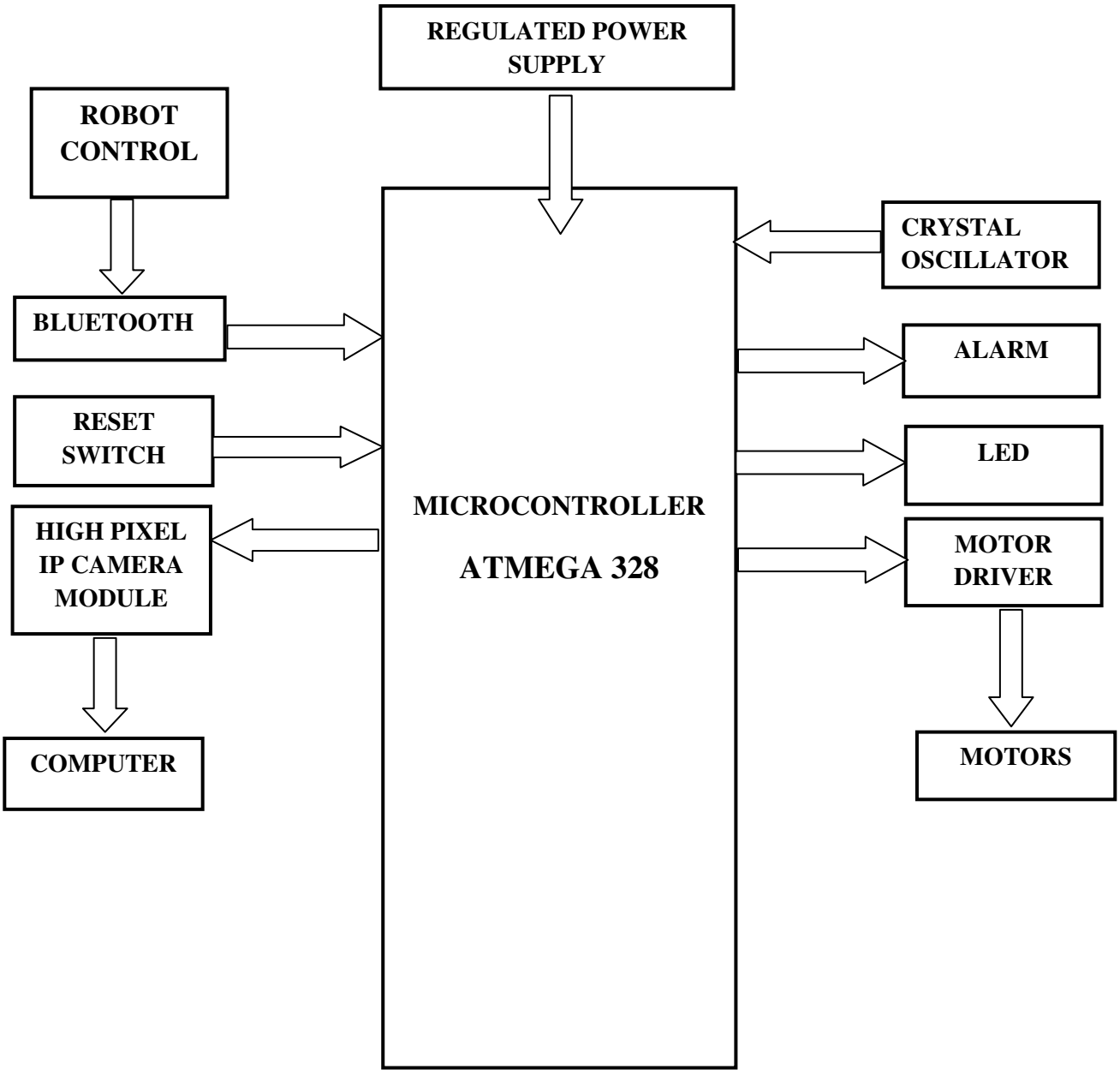

Figure 2: Block Diagram of Proposed System

V. CRACK DETECTION USING IMAGE PROCESSING

Image processing plays an important role in processing of images using some mathematical operations with the help of any form of signal processing for which the inputs can be images or videos. There are different parameters and characters that depend upon the output of the image in the image processing. Images in the image processing techniques are treated as two or three dimensional structures. Image processing technique provides accurate result compared to other conventional methods. That is why different image processing techniques has been used for the image based analysis of crack detection.

Figure 3: Image Processing Architecture

1. Firstly, the images of the structures for the process of crack detection have been collected by using camera or any other sources.
2. The collected images are preprocessed after the segmentation in which different methodologies are done in order to making it an efficient one for the purpose of image processing.
3. In the image processing step, some of the techniques are employed to process the deducted image sample.
4. By using the result of the processed image, crack has been detected on the structure.
5. Finally, the detected cracks have been extracted based on different parameters like shape, size, width, depth etc.

VI. IMAGE PROCESSING STEPS ON THE PROPOSED SYSTEM

First step is the color to gray level transformation involved in image processing unit that will convert the true color into the gray level intensity of the image. During the process the amount of the image data decreases by retaining the luminance by eliminating the hue and saturation information. Gray level image obtained is then processed with the improved subtraction processing. This process will generally removes the slight variations like shadings or irregularly illuminated conditions. It is used in the processing of the noisy concrete surface for crack visualization. Firstly the smoothed image is generated by applying a median filter on a gray level image is subtracted from the smoothed image. Gaussian low pass filter is used to smooth the images. Gaussian filter is one of the important filter whose impulse response is a Gaussian function. The main aim to adopt this filter is to connect the small gap of the crack line and also to adjust the distortion of the crack shape.

In the creation of binary image by thresholding an input gray level image is converted to a binary image where the values of points are expressed by 0 o 1. Thresholding is the simple and intuitive method in image segmentation. Morphological image processing is the last step of image processing unit in which it can be used to extract the image components such as shape of cracks. There are dilatation, erosion, opening, closing, labeling in morphological operations.

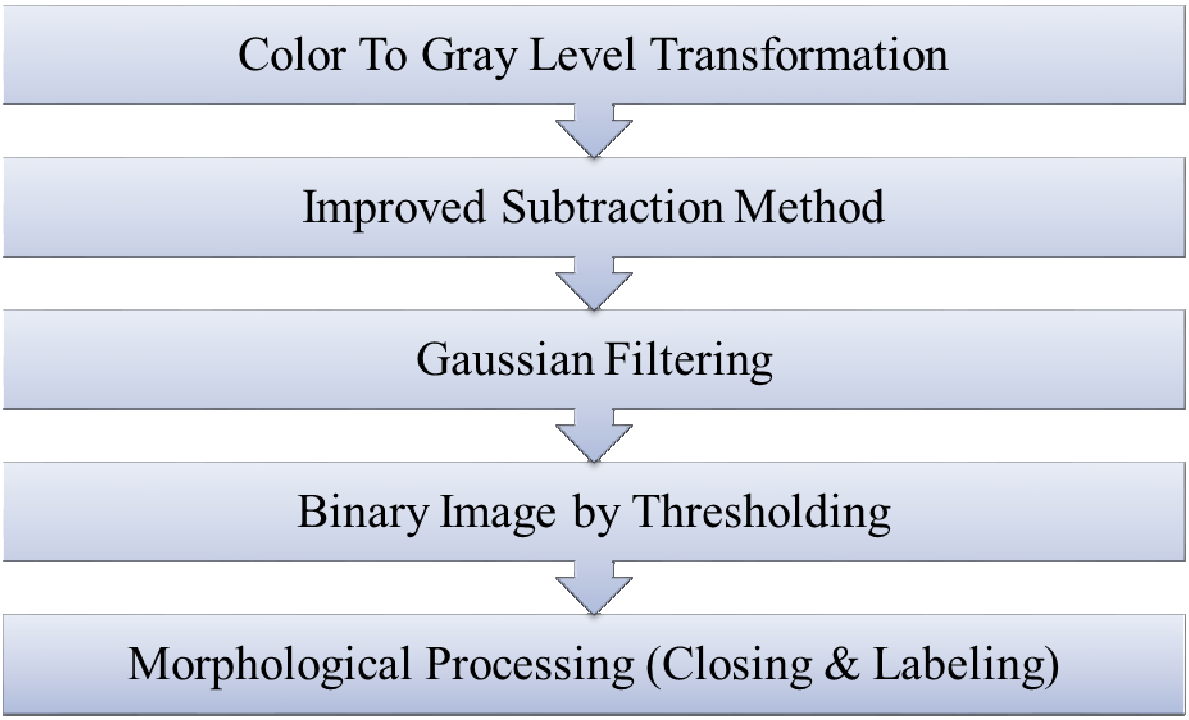

Figure 4: Image Processing Steps

In the proposed algorithm closing and labeling are used. Closing is used to connect the narrow breaks and long thin gulfs, eliminate small holes and fill gaps in the crack where as in labeling the neighboring connected components are recognized as a single object and all the points in the single object are labeled with the same number.

VII. RESULTS AND DISCUSSIONS

The proposed automated crack detection system consists of following main parts:

1. A robot which will navigate on the bridge surface to collect the surface image at predetermined locations.
2. A high resolution camera to collect images of surface.
3. A global map for locating position of cracks.

The main objective of this proposed system is to detect the crack on the bridges by using the setup designed, which is very simple and easier for the detection process and for the further maintenance by replacing the manual procedure currently employed. The design procedure and the software programming related to this proposed system are very simple and can be easily adopted.

In order to evaluate the safety of a concrete structure, a method to detect cracks from camera image was proposed. First, it was possible to visualize the concrete crack easily through the image processing techniques such as improved subtraction method, filtering and segmentation method. Second, the existence of cracks in many images could be automatically identified

Figure 5: Original Image

The figure shows the original image and output of the image processing steps by using the proposed algorithm were

(a) Original image
(b) Result of the original subtraction processing
(c) Result of the whole image processing using (b).
(d) Result of the improved subtraction processing
(e) End result of the total image processing including the improved subtraction.

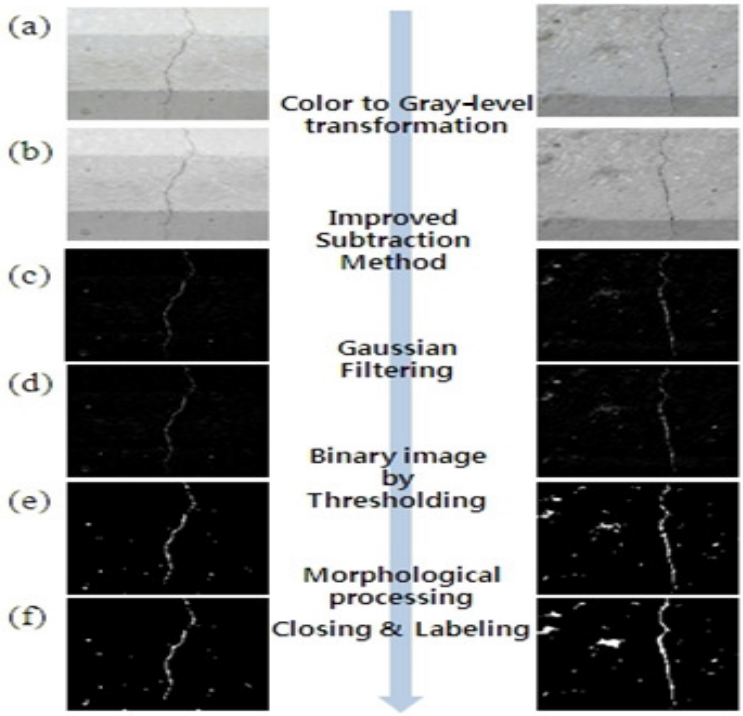

Figure 6: Result of the Proposed Image Processing

VIII. CONCLUSIONS

By adopting the cost effective automated crack detection scheme for the purpose of crack detection, it will have a great impact in the maintenance of the structures which will also helps to avoid the accidents due to the cracks created on the structures to a certain extent. The proposed system can be implemented in the regions where manual inspection is not possible and also where there are spatial constraints in the structures. The system proposes crack detection and a mapping system for the bridge surface using a mobile robot and it is also capable of providing a global crack map for locating the cracks on the surfaces which can be detected and corrected at the earliest stage will reduce the accidents to a certain extent. The mechanism of the proposed system works on a simple principle and there is no complexity in the circuit designed thus it can be implemented easily with reduced cost.

REFERENCES

[1] Prateek Prasanna, Kristin J. Dana, Nenad Gucunski, Basily B. Basily, Hung M. La,Ronny Salim Lim, and Hooman Parvardeh, "Automated Crack Detection on Concrete Bridges", IEEE Transactions On Automation Science And Engineering, Vol. 13, No. 2, April 2014

[2] Wenyu Zhang, Zhenjiang Zhang, Dapeng Qi and Yun Liu, "Automatic Crack Detection and Classification Method for Subway Tunnel Safety Monitoring", Sensors 2014, 14, ISSN 1424-8220,19307-19328.

[3] Seung-NamYu, Jae-HoJang, Chang-SooHan, "Auto Inspection System Using A Mobile Robot For Detecting Concrete Cracks in a Tunnel, Automation in Construction", Volume 16, Issue 3, May 2007, Pages 255-261

[4] Tung-Ching Su, "Application of Computer Vision to Crack Detection of Concrete Structure", IACSIT International Journal of Engineering and Technology, Vol. 5, No. 4, August 2013

[5] Hyeong-Gyeong Moon and Jung-Hoon Kim, "Inteligent Crack Detecting Algorithm On The Concrete Crack Image Using Neural Network".

[6] Ronny Salim Lim, Hung Manh La, Weihua Sheng , "A Robotic Crack Inspection and Mapping System for Bridge Deck Maintenance", IEEE Transactions on Automation Science and Engineering , Volume: 11, Issue 2, April 2014, Pages 367 – 378.

[7] H. Kim, S.H. Sim,S. Cho,"Unmanned Aerial Vehicle (UAV)-powered Concrete Crack Detection based on Digital Image Processing" in 6th International Conference on Advances in Experimental Structural Engineering and11th International Workshop on Advanced Smart Materials and Smart Structures Technology August 1-2, 2015, University of Illinois, Urbana-Champaign, United States.

[8] Gajanan K. Choudhary and Sayan Dey, "Crack Detection in Concrete Surfaces using Image Processing, Fuzzy Logic, and Neural Networks " in Fifth International Conference on Advanced Computational Intelligence (ICACI), 2012 IEEE.

[9] Ahmed Mahgoub Ahmed Talab, Zhangcan Huang, Fan Xi, Liu Hai Ming, Detection crack in image using Otsu method and multiple filtering in image processing techniques, Optik International Journal for Light and Electron Optics, Volume 127, Issue 3,Pages 1030-1033, February 2016.

[10] S.Arul Mozhi, Avanti Prabhakaran, V.Mathivathani, R. Priyank, Crack Detector Robot Using LED-LDR, International Journal of Scientific & Engineering Research, ISSN 2229-5518, Volume 5, Issue 1, January-2014

[11] Mohammad Salman, "Image Based Detection and Inspection of Cracks on Bridge Surface Using an Autonomous Robot", International Journal on Recent and Innovation Trends in Computing and Communication ISSN: 2321-8169 Volume: 3 Issue: 2.

[12] S. N. Yu, J. H. Jang, and C. S. Han, "Auto inspection system using a mobile robot for detecting concrete cracks in a tunnel," Autom. Construction, vol. 16, pp. 255–261, 2007.

[13] XU Xuejun and ZHANG Xiaoning, "Crack detection of reinforced concrete bridge using video image" in Springer - Verlag Berlin Heidelberg 2013, DOI: 10.1007/s1177101317755

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