A Crack Detection System Deployed by an Underwater Roving Vehicle

S. G. Dabade[1], Prashik Lanjewar[2], Aditya Mandlik[3], Maheep Sharma[4], Kumbha Singh[5]
[1, 2, 3, 4, 5] Department of Mechanical Engineering
[1, 2, 3, 4, 5] Sinhgad Institute of Technology, Kusgaon (Bk), Lonavala,

Abstract- *This project proposes a robotic system for searching cracks in bridges and submerged underwater structures (metallic or concrete). This robotic system for structure inspection has been developed with the aim of checking the safety status of a real bridge and gathering accurate data such as crack. The paper proposes a review of robotic system for searching cracks in underwater structures. The developed robot system is composed of the moving mechanism mounted on a specially designed robot and the vision system for precise inspection. Especially, this project emphasizes the system integration method to design and control the entire robot system. The paper finds its applications for the crack detection for underwater structures like beam of bridges, oil and gas platforms, pipelines and risers, ship hulls and harbor installations.*

Keywords- ROV-Remotely Operated Underwater Vehicle. AUV-Autonomous Underwater Vehicles. ANSF- Adaptive Nonlinear State Feedback Controller. MEMS - Micro-MachinedSensors. DTMF - Dual Tone Multi-Frequency. UTS - Ultrasonic and Tactile Sensors.

I. INTRODUCTION

The number of bridge construction has been gradually increased. According to the increase of bridge construction, the number of bridges to be inspected has been annually increased at the same time. Although the robot technologies have advanced in a variety of industrial areas, the robot application technologies for the safety diagnosis and maintenance of real bridges have lagged behind. Currently, the bridge inspection and maintenance have been manually conducted by the educated inspection workers in poor surroundings. As a matter of fact, the inspection workers check the safety status beneath the bridge only by counting the number of cracks, measuring the maximum width of the crack line and taking pictures. Thus the accuracy and quality of safety report become greatly different according to the diligence of inspection workers. Also, since the bridge inspection is performed outdoors, especially beneath the bridge, there can be problem concerning the safety of inspection workers. Inspection workers stand on temporary scaffolding in order to inspect the safety status of bridges.

An industrial disaster can be always caused during the manual inspection. Also, the absence of the safety device can cause it in performing the bridge inspection. So, the improvements of working environment have become the first consideration in bridge inspection. Hence, there is a necessity to develop the bridge inspection robot system by using the unmanned robotic technologies. An inspection robot is the most useful when it can carry sensors into inaccessible or hazardous areas, thereby making the task safer for the inspection workers. For example, the robot system for the underwater inspection of the bridge piers has already been developed. In this project, we aim at raising the consistency of inspection results, improving the exactness of annual safety reports about the bridges, and reducing the industrial disasters. With these aims, we will suggest a robotic system for detecting cracks with vision.

II. RESEARCH AND COLLECTION OF IDEA

Identification: Construction of a remotely operated remotely operated vehicle to detect underwater metallic surface cracks with great measurement and accuracy.

Previous work:

Crack formation is one of the early signs of degradation. Hence, detection of cracks at early stages helps take necessary precautions in order to prevent further damage. Current traditional methods of crack detection on a bridge deck involve significant manual labor. Grids are first marked along the entire length of the bridge. A skilled engineer then walks from one section of a grid to another closely inspecting the surface and marking the location of cracks. Apart from being time-inefficient, such methods heavily depend on the experience of the specialist. This method also tends to be inaccurate. Failure of detection of these initial cracks might lead to decrease in longevity of bridge and sometimes collapse Prateek Prasanna (2014), specified. NDE techniques may include ground-penetrating radar to detect flaws and corrosion inside the structures and sensor technologies that monitor traffic loading, cracks due to fatigue and corrosion, overloads and various environmental conditions. One of the new methods that is being incorporated into this testing scheme is crack-detection using image processing and pattern recognition techniques.

The bottom-following or seabed tracking problem has been identified as one core task in an increasing number of scientific (and military) applications that require autonomous underwater vehicles (AUV) to execute traverses at a constant altitude from the sea bottom .A solution was given by Aras Adhami et al.(2014) .They proposed a solution for the automatic bottom-following problem for a low cost autonomous underwater vehicle. They consider the case that the seabed profile is not known in advance, and showed that it is possible to solve the bottom-following using only one echo sounder and without the need to measure the vertical velocity component (heave velocity). Doing field work on the sea floor Tom Kwasnitschka (2013) presented Photogrammetric techniques to yield 3D visual models from ROV video. Remotely Operated Vehicles (ROVs)have proven to be highly effective in recovering well localized samples and observations from the sea floor. In the course of ROV deployments, however huge amounts of video and photographic data are gathered which present tremendous potential for data mining. He present a new work flow based on industrial software to derive fundamental field geology information such as quantitative stratigraphy and tectonic structures from ROV based photo and video material .

The experimental details of an experiment under experimental marine biology and ecology. From 2008 to 2014, an ROV was deployed to track the at-sea behaviour of loggerhead turtles in the North west Atlantic Ocean presented by Ronal J. Smolowitz,*, Samir H. Patel (2015). Seventy turtles were tracked, totaling 44.7 h of direct turtle footage. Divine Maalouf (2015) in his paper showed that Underwater vehicles have gained an increased interest in the last few decades given the multiple tasks they can accomplish in various fields ranging from scientific to industrial and military applications. For this reason, it is less risky such as deep seas and oceans.The underwater manipulator has become an essential tool of underwater vehicles for performing underwater works such as drilling, cutting in coordinated tasks, and sampling, coring, and connector-mating in the fields of scientific research and ocean engineering. (Antonelli et al., 2000; Kim et al., 2002; Marani et al., 2006, 2007, 2009). Autonomous manipulation, which is a major part of studies on manipulators mounted on underwater vehicles, has been the main research issue in the field of underwater vehicle-manipulator system (UVMS)

A hydraulic hose repair system is presented that was developed for use at the Deepwater Horizon accident site by Alexander Slocum(2015). The system can be deployed with a single ROV with two controllable arms. One arm holds the device and the other arm pushes a severed hose into the device. In particular, the detection of cracks in buried pipes is a crucial step in assessing the degree of pipe deterioration for municipal and utility operators as suggested by Sunil K. Sinha(2006). The key challenge is that whereas joints and laterals have a predictable appearance, the randomness and irregularity of cracks make them difficult to model.

Modern industries use many types of robots. In addition to general robotic arms, bipedal, tripedal, and quadrupedal robots, which were originally developed as toys, are gradually being used for multiple applications in manufacturing processes. P.S. Pa(2009) presented that under additional loads, the four feet of the quadrupedal robot reinforce its carrying ability and reliability compared to bipedal or tripedal robots, which helps it to carry more objects and enhances functionality.

II. STUDIES AND FINDINGS

1. Relays:

i. Relay Basics:

A relay is an electrical switch that uses an electromagnet to move the switch from the off to on position instead of a person moving the switch. It takes a relatively small amount of power to turn on a relay but the relay can control something that draws much more power. Ex: A relay is used to control the air conditioner in your home. The AC unit probably runs off of 220VAC at around 30A. That's 6600 Watts ! The coil that controls the relay may only need a few watts to pull the contacts together (fig. 3.1.1 and 3.1.2).

This is the schematic representation of a relay. The contacts at the top are normally open (i.e. not connected). When current is passed through the coil it creates a magnetic field that pulls the switch closed (i.e. connects the top contacts). Usually a spring will pull the switch open again once the power is removed from the coil.

ii. Relay Selection:

Relays (and switches) come in different configurations. The most common are shown to the right. Single Pole Single Throw (SPST) is the simplest with only two contacts. Single Pole Double Throw (SPDT) has three contacts. The contacts are usually labelled Common (COM), Normally Open (NO), and Normally Closed (NC). The Normally Closed contact will be connected to the Common contact when no power is applied to the coil. The Normally

Open contact will be open (i.e. not connected) when no power is applied to the coil. When the coil is energized the Common is connected to the Normally Open contact and the Normally Closed contact is left floating. The Double Pole versions are the same as the Single Pole version except there are two switches that open and close together.

iii. Relay Circuit:

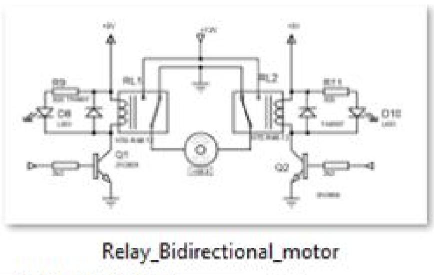


Fig.3.1. 1

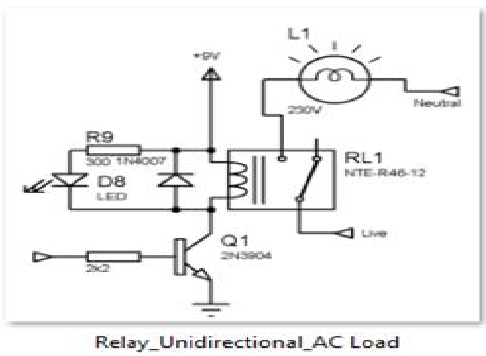


Fig. 3.1.2.

iv. Component Specifications:

Table 3.1.1

Component Name	Price List
6v DC relay	70
SL100 Transistor	35
Resistors 270ohm 2.2k	 1 1
3mm Red Led	1
In4007 Diode	1
3-pin Screw Terminal	7

2. AT89S52:

i. Description:

The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The device is manufactured using Atmel's high-density non-volatile memory technology and is compatible with the indus-try-standard 80C51 instruction set and pinout. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory pro-grammar. By combining a versatile 8-bit CPU with in-system programmable Flash on a monolithic chip, the Atmel AT89S52 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications. The AT89S52 provides the following standard features: 8K bytes of Flash, 256 bytes of RAM, 32 I/O lines, Watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry (as in pin f**ig**.3.2.1). In addition, the AT89S52 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The Power-down mode saves the RAM con-tents but freezes the oscillator, disabling all other chip functions until the next interrupt or hardware reset.

ii. Pin Configuration:

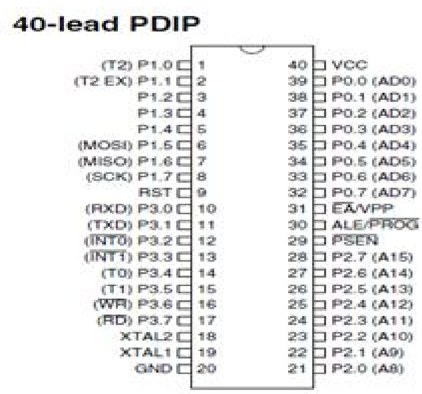
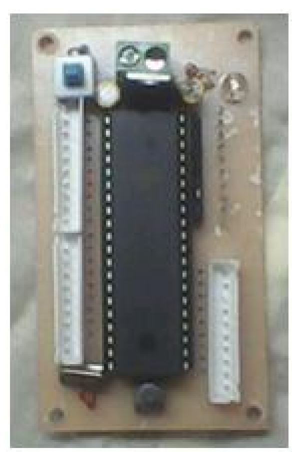


Fig. 3.2.1



iii. Power Supply:

A power supply is a device that supplies electric power to an electrical load. A regulated power supply is one that controls the output voltage or current to a specific value; the controlled value is held nearly constant despite variations in either load current or the voltage supplied by the power supply's energy source.

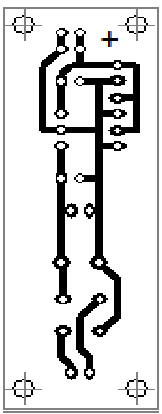


Fig3.3.1 Layout

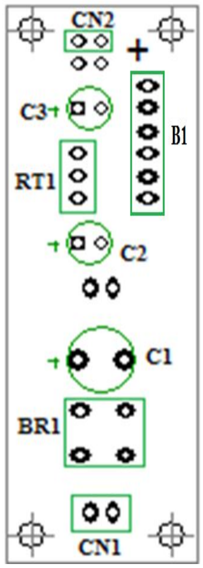


Fig 3.3.2 Component Diagram

i. Component List:-

Value	Component	Abbreviation
WA10	BRIDGE RECTIFIER	BR1
7805/7809/7812	REGULATOR	RT1
2200uF	CAPACITOR	C1
10uF	CAPACITOR	C2
100uF	CAPACITOR	C3
-	CONNECTOR	CN1
-	BUG STRIP	B1

Table 3.3.1

4. Gaussian Blur Image Processing. (Crack Detection)

The various ways of obtained input image processing for detection of c racks are spatial domain filtering, high pass filter, median filter, laplacian filter image processing, etc. We use a more feasible and easy technique called Gaussian blur technique.

This technique is easy to implement. It uses the concept of sorting out an image in convolution kernels and then weighing each kernel by directly applying the matlab input programme. Since the image processing can be abit tedious job, its processing time is slow.

A convolution kernel is a 9x9 grid square division of an image (fig.3.4.1 and 3.4.1) with the target kernel at the centre of a 9x9 formation. Mark the whole grid in sequence and proceed with the process.

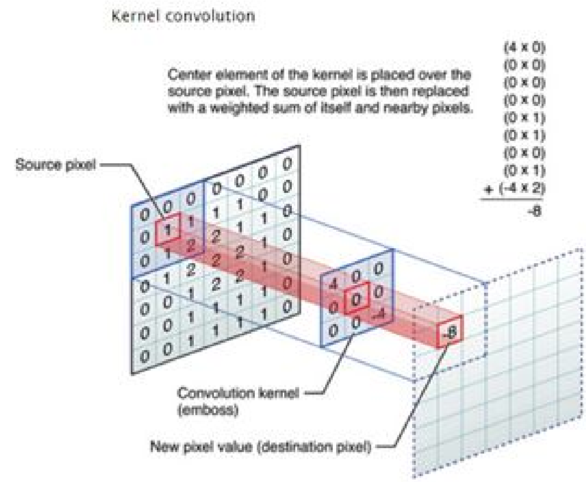


Fig 3.4.1Kernal Convolution Grid Distribution

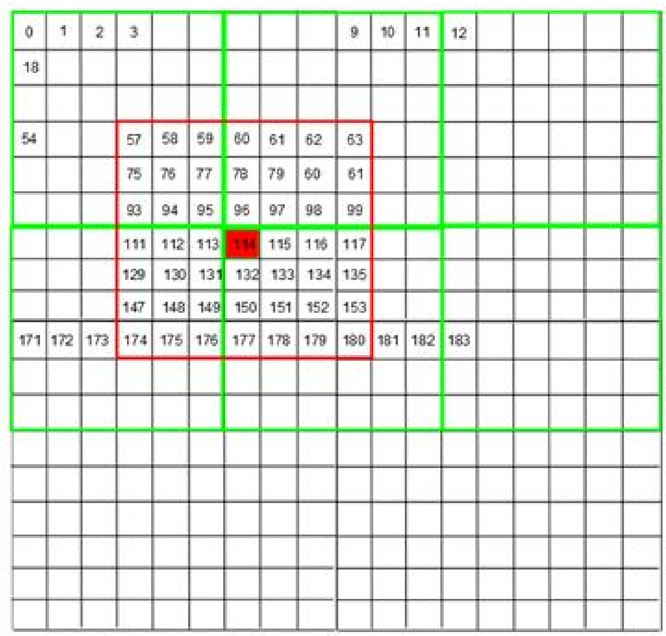


Fig 3.4.2. Specific Pixel Targeting

5. Computer Vision Based Crack Detection and Analysis.

One of the new methods that is being incorporated into this testing scheme is crack-detection using image processing and pattern recognition techniques. This project concentrates on the detection and analysis of cracks based on machine-learning based classification algorithms. Methods discussed here include local curve fitting and feature based classification using support vector machines. The aim of this project is to build an automated crack-detection system that can be successfully integrated with a robot such that the process would be more time and cost-elective. As part of this project, a bridge was surveyed in Gainesville, Virginia (Courtesy: CAIT, Rutgers University). Video images were collected along the entire bridge deck and still frames were extracted from these videos. Since labelled data was unavailable, the labelling for cracked and uncracked points was done by visual inspection Forty crack and forty non-crack points were selected in each of the 50 images and their co-ordinates were saved.

A 9*9 window around the feature points was selected and their pixel values as obtained from the canny edge detector was saved in subsequent rows of 9 elements each. A second set of feature vectors was obtained with the images blurred, with the notion that spurious edges would be removed. SVM algorithm was implemented for linear, quadratic and RBF (Radial Basis Function) kernels respectively using bioinformatics toolbox in Matlab. The last 500 observations were used as the validation data. Sub-regions with 30*30 neighborhoods were selected in grayscale image space. Subsequently, curves were fitted to pixels whose intensity lied a fixed percentage below the average block intensity. The curve fitting was done using both Random Sample Consensus (RANSAC)10 and least squares estimation, but in most cases, least squares estimation was found sufficient. The blue lines in Figure 5 are the local curves.

Feature vectors are computed as input to both training and testing phases of the classifier. In order to identify feature vectors, histogram plots are then obtained for the following:

1. In 30*30 neighbourhoods containing the detected local curves
2. Along the detected local curves.

The method implemented uses a histogram-based classification algorithm. The detection rate of the classifier has been found to be approximately 76%

In fig 3.5.1, Original images along with classification results. Red lines show correctly detected cracks and blue lines show the correctly detected non-crack regions. Green lines show undetected cracks and the lines in cyan show the non-crack regions classified as cracks.

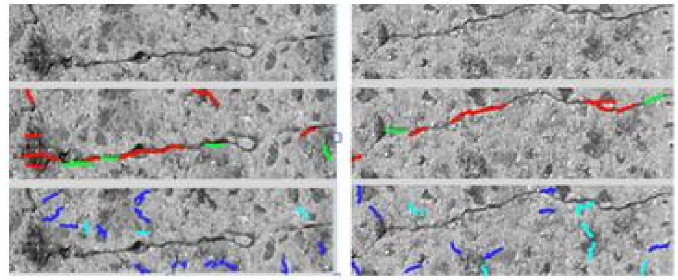


Fig. 3.5.1.

VI. CONCLUSION

The robotic system for unmanned bridge inspection has been developed for a real application. Till now, most bridge inspections have been manually done by counting the number of cracks, measuring their lengths and widths and taking their pictures. In this case, the quality and reliability of safety report on bridges can be subjective according to the inspection worker. In this paper we have shown that the suggested robotic system can be an alternative of the manual bridge inspection. The proposed bridge inspection system is composed of three main parts; a specially designed car, robot mechanism and control system for mobility, and machine vision system for the automatic detection of cracks. Ultimately, this robot system has been developed for gathering accurate data in order to record the annual changes of the bridge's safety circumstances as well as checking the safety status of bridges. Finally, the effectiveness of the crack detecting and tracing algorithms was shown through a few experiments.

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