# DEVELOPMENT OF REMOTE CONTROL SYSTEM FOR BRIDGE INSPECTION USING ROBOT AND DIGITAL IMAGE PROCESSING TECHNOLOGY

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## ABSTRACT

After 1994, highway bridges are maintained under the Special Law on Structure Safety in Korea. To keep a structure good condition, inspection of the structure has to be performed periodically. The inspection is hard work and needs a lot of time and many inspectors to inspect the structure that is important or damaged. Generally, This contains subjectivity of inspector, and so the result of inspection is not objective and reliable. And the inspection has a limit to only the bridges that access is possible to bottom of it.

The purpose of this study is to develop new inspection technique and equipment to solve above problems and to provide convenient inspection work. The new inspection method may be able to make the inspection of bridge deck more efficient and reliable. This new inspection technique makes inspection job scientific and systematic. Digital image processing technology and Robotics are used in this inspection system.

This study can be divided into three parts. 1) A study on development of digital image processing system. This system can stitch each image and detect cracks of bottom of bridge deck. Also, It can extract an investigation drawing from the picture. 2) Development of remote controlled robot system with camera and boom system. Pictures of bottom of bridge deck can be captured easily by using robot controlled on the deck remote. 3) A study on construction of Database of digital images obtained by remote controlled robot system. We can compare the pictures obtained periodically. So we can find changes of surface and crack propagations from the images.

As a result of this study, inspection work with naked eye could replace with the new inspection system. The system is manufactured including digital camera module, remote controlled robot, boom system and vehicle, and global positioning system.

## KEY WORDS

Bridge Inspection, Digital Image Processing, Remote Controlled Robot System, Bridge Inspection Equipment.

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## INTRODUCTION

The intent of the maintenance of the structure is to improve, maintain and maximize the functionality of the road by enabling to detect in early stage any damages that may arise due to deterioration and to correct the problem efficiently and effectively in order to accommodate commuters and to ensure their safety. Inspection is the fundamental and foremost important procedure in the maintenance of the structure as it is the first step in detecting any active and/or potentially hazardous conditions. In South Korea, in accordance with the "Special Law on Structural Safety" designated in 1993, each assigned district organization performs systematic maintenance and evaluations on a regular periodic basis.

However, despite the apprehension and the awareness of the importance of these procedures, there exist a number of significant problems under the current system.First, under the current system, the scope of the inspections are limited to the areas that are accessible to reach, as majority of the examination procedures are performed roughly by visual evaluations through naked eye although it is critical that in-depth examinations of more sophisticated and significant structures require significant investment of time, labor and technology. Second, since the examination relies heavily on the subjective opinions of the inspector the credibility and objectiveness of the evaluation remains as a complication. In addition, this otherwise convenient inspection vehicle currently used during the examination inevitably requires temporarily blockage of the infrastructure as it is placed at super-structure and thus causes great inconvenience to the drivers and furthermore consequently results in economic loss.

Accordingly, the objective of this research is to provide more effective and rational methods in inspecting and examining the structure and the bridge-decks while accommodating and assisting the inspectors and their affiliated organizations. This system implements the rapidly improving Digital Image Processing Technology, IT, and robotic technology to administer moreover defined and accurate scientific and systematic inspection. The research is executed into three components. First, by developing a specific digital imaging technology, the system can realistically capture, obtain, and incorporate the images of any cracks under the bridge deck allowing higher accuracy of the evaluation. Next, by developing a remote controlled robot system and transmittal inspectors can conveniently command and obtain necessary visual images of the structure. Furthermore, by integrating acquired materials from each periodic inspection, we can compare and analyze the changes and even detect formation of potential cracks.

## STATUS OF STRUCTURAL INSPECTION AND TECHNOLOGY DEVELOPMENT

### VARIOUS TYPES AND METHODS OF INSPECTION

The inspection works on bridge are followed in accordance with the inspection guidelines stated in 'Safety Inspection and Precise Analysis of Evaluation Act (2003),' and the period of inspection, and the level of the inspection and is performed through early stage inspection, defined inspection and emergency inspection. The execution procedures of the inspection assignment first designate the condition levels of the member element, evaluate the

significance of each element and prioritize the overall levels and determine the appropriate repair or reconstructions correspondingly.

It is apparent and thus reasonable to assume that under current system a subjective opinion of the inspector plays a significant role in the evaluation of the inspection. Reason being, in the case of KHC(Korea Highway Corporation), single inspector, inspects and manages approximately 138 structures on a yearly basis. Considering the relative frequency of various types of inspection, each inspector needs to inspect approximately 14.5km in addition to any tunnels and culverts that inevitably exceed his/her workload to great extent.

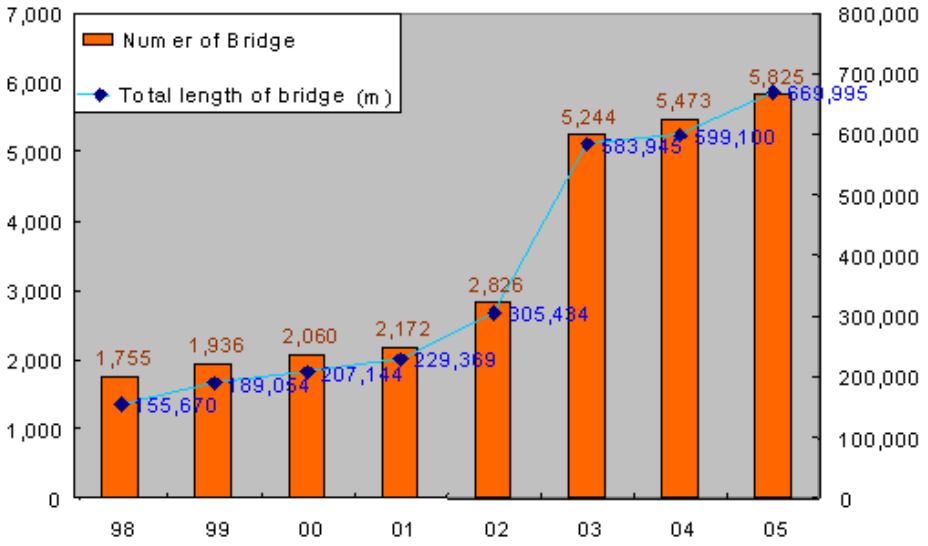


Figure 1: The current state of highway bridge in Koea

## INSPECTION EQUIPMENTS AND FACILITY

### Inspection Equipments

Beam Lifter and Inspection Vehicles are two major equipments used for the inspection. As shown in Figure 2 the Beam Lifter is used to inspect abutments, piers, bearings and bottom of deck under the bridge. However, Beam Lifter cannot be used in areas with high clearance or areas unapproachable if there is a creek or river under the bridge. As shown in Figure 3 the Inspection Vehicle operated by the inspector is used to examine the exterior of the structure of relatively closer to bottom of deck and coping. Therefore, it is used only on specific and limited areas of the structure.

Figure 2: Inspection of bean lifter

Figure 3: Inspection of special vehicle

**Inspection Facility**

The inspection facilities are is mainly divided into two types, one is built-in facility(Figure 4) at coping, and the other type is movable system(Figure 5) installed under deck. This examination system makes it possible to inspect on a routine basis the major structures without limiting or disabling traffic flow. This will allow crews to detect and assure the status, condition and the proper functions of the structure. Bridge inspection facility is constructed to be able to do maintenance working, considering the location of bridge, superstructure type, and other circumstances.


Figure 4: Built-in facility at coping

Figure 5: Movable system installed under deck

However, in order to utilize these facilities it must possess stable mobility from top to bottom and the inspection procedures are performed on high altitude which requires additional attention of the safety of the inspector. In addition, for example, any results acquired in the existence of limitations to access such as bottom of deck can lack in their credibility and accuracy.

### STATUES OF DEVELOPMENT OF EXAMINATION RELATED TECHNOLOGY

Application of digital optical technology, method using ultra-sonic wave, examination of core sample, total comprehensive application integrated these technologies are currently widely used for diagnosing and evaluating structures and are continuously being developed. The Optical Method using digital optical technology is a technique used to analysis after scaling the images captured by digital camera by using relationship of pixel and FOV(Field Of View) of the pictures. This method also has some merits in objectivity and reliability. The method using Ultra-Sonic Wave is used to detect defects inside of structure from the images calculated by using the relation incidence wave and reflection wave and tomography. Other total applicable technologies includes IT technology, communication information technology and robotic technology combined with digital imaging and analyzing technology are used to increase the objectivity and the credibility of the procedures.

## OUTLINE OF THE SYSTEM

### ORGANIZATION OR COMPONENTS

The development of Remote Controlled Examination System consists of live digital visual technology, remote controlled robot and transmittal technology and integrated information technology. As shown in Figure 6 a digital camera, lighting fixtures and ultrasonic distance measuring module are secured on to this Remote Controlled Examination System and is delivered to the exact site to be inspected via remotely controlled transmittal system. The Robot is secured to the edge of the boom and is placed on to a small vehicle. Inside the vehicle is a control panel room to command and access remote transmittal system to command and navigate the robot and its transportation system. The control room is also equipped with imaging software capable of analyzing and storing acquired data.

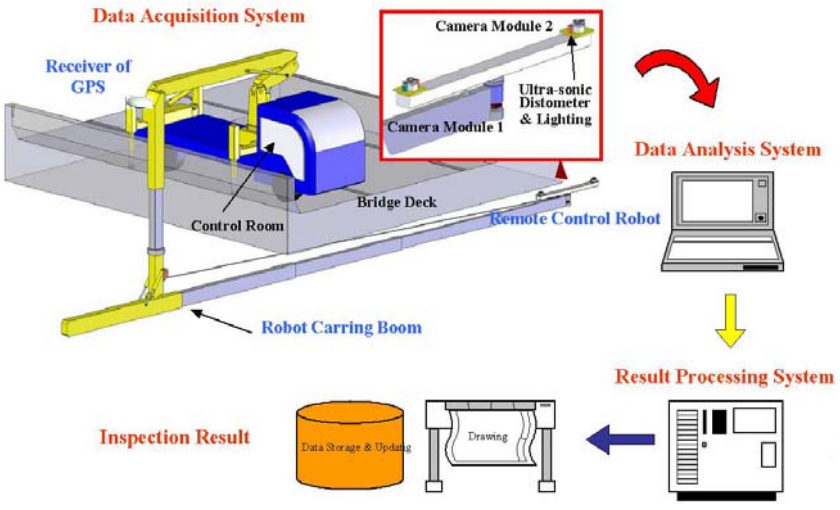


Figure 6: An outline of the bridge inspection system

This system is situated off the shoulder next to the site(s) to be inspected and performs associated procedures in the following manner.

### CONTROLLER SYSTEM

Remote Controlled Robot, transporting Boom, Digital Camera Module and site identifier are comprised and the overall system is powered by extension of electric generator fixed onto the mobile vehicle.

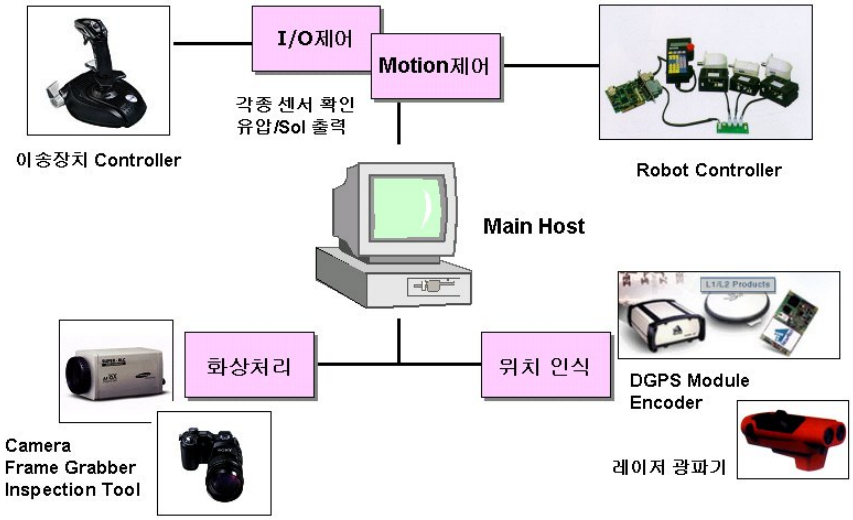


Figure 7: Components of Controller System

### NAVIGATION SYSTEM

It is very difficult and extremely complicated procedure to obtain a visual image grid from and above the bridge. In general, a robot attached with Servo Motor can be control and operate with Nano- precision making it possible to accurately provide coordinates, however, its mobility is limited. Accordingly, in order to acknowledge the precise location of bridge, the remote controlled robot secured to the edge of transportation boom must move to the Grid formed at the bottom deck of the bridge, which requires a solution that will provide an accurate location of the site.

However, it is difficult and often impossible to apply the existing Servo Motor based controller to embrace the entire size of the bridge as the perimeter of the robot is overly substantial. Therefore, in this research, DGPS (Differential GPS) is used to precisely pinpoint the exact location of the site to be inspected.

## LIVE DIGITAL VISUAL SYSTEM

### IMAGE PROCESSING PROGRAM

The purpose of Live Digital Visual System is to achieve, organize and provide all accomplished results and ultimately delivers a method to correlate and analyze related materials efficiently. The Live Digital Visual System is divided into two broad areas, the data collecting system and the data analysis system.

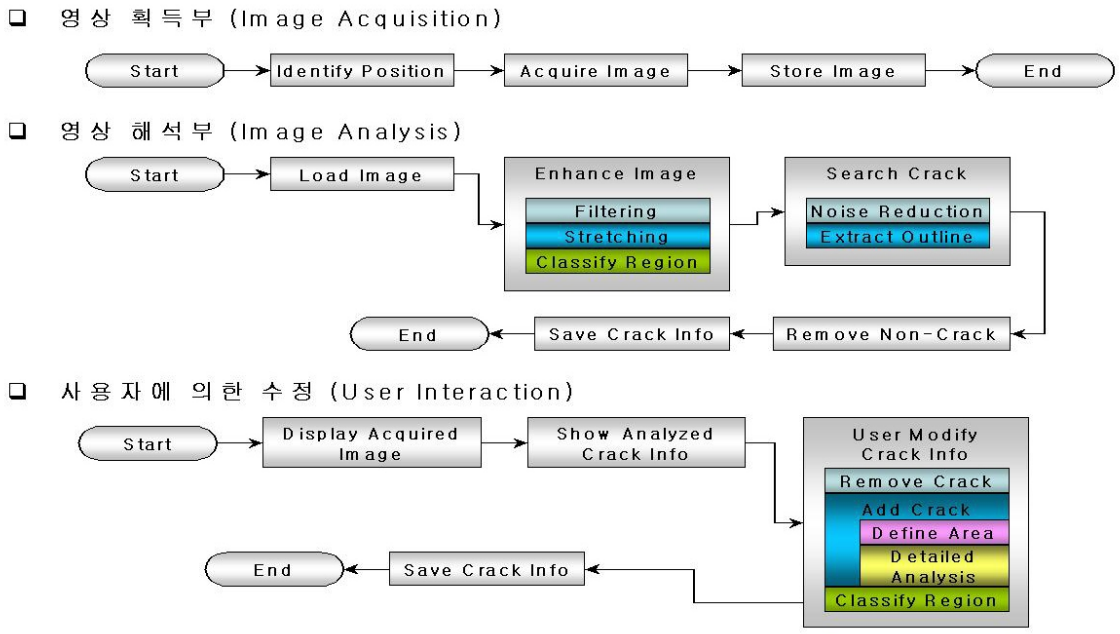


Figure 8 Live Visual Data Analysis System Layout

### DATA COLLECTING SYSTEM

Data Collecting System obtains necessary images from the bridge deck by controlling the hardware such as camera and robot module while the Data Analysis System consists of software materials that are managed by the user in analyzing the data.
Figure 8 shows Data Analysis System consisting of Visual Acquisition, Visual Analysis and User Adjustment

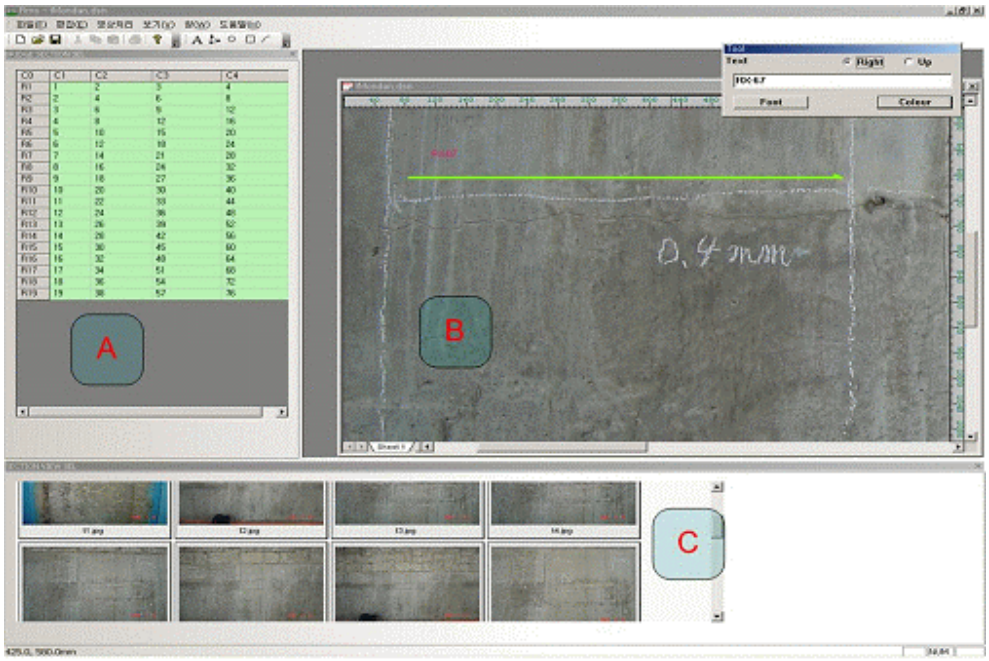


Figure 9: shows Data Analysis Software GUI.

The Data Management System is a kind of management tools designed to have some functions such as converting the image data obtained from 2 cameras to Data-Base format, searching and storing the data. As shown at Figure 9, the function of the system is mainly divided in 3 modules. As shown at Figure 9 (A) and (b), panorama algorithm is used to stitch each image obtained in a whole image, so we can control easily the image data including damage status of deck.

## REMOTE CONTROL INSPECTION ROBOT

Remote control inspection robot installed at the end of 3$^{rd}$ boom of Whole System displayed in Figure 11 consist of Camera module which can obtain the images of the bottom of deck as shown Figure 10 and 11 servo motors. And the robot can be moved alone, so the time to capture a image can be reduced. Additional cylinder is installed at T-Axis to reduce vibration of boom due to wind or free vibration of the bridge and to move the Robot.

Figure 10: Remote Control Inspection Robot for Bridge

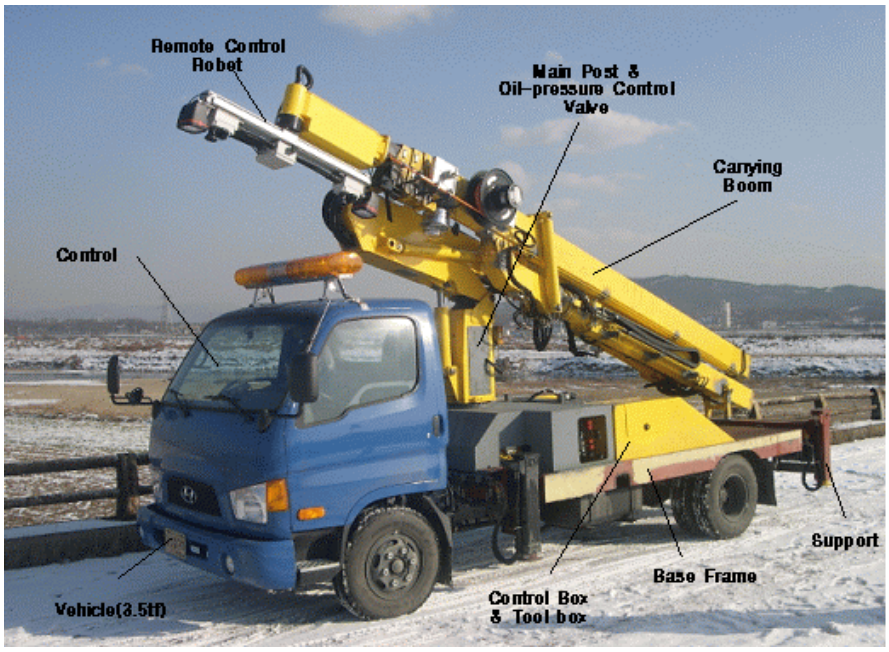


Figure 11: The vehicle and carrying system for the Robot

## CONCLUSION

Bridge Inspection is the most important and fundamental work that is carried out preferentially before evaluation of the Load Capacity, repair or reinforcement a bridge. And it helps we can decide whether the bridge is healthy or not. Actually, inspection works are depending on examination with the naked eye, subjective opinion entirely, so it is hard to trust the inspection reports. In this study, in order to solve the many problems above mentioned and systematize the inspection works, we have been trying to develop the Remote Control Inspection System for bridges using Image Process Technology.

As a result of this study carried out up to now, the Remote Control Inspection Robot, Image Processing Program and Software that can sense the position of each captured picture of deck from the digital camera are developed.

We believe that this inspection system can help inspector to find defects of bridge and guarantee safety of inspectors and a systematic inspection works could be achieved. The whole system displayed in Fig 6 also is manufacturing. Verification of most components were completed and we are making up for the partial weak points in the system to improve its performance.

We also expect that a more useful Data-Base could be built as linking the image data obtained from the system with HBMS(Highway Bridge Management System) which is developed and using in our company.

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