A LIGHTWEIGHT IMAGED BASED BRIDGE INSPECTION SYSTEM USING FISHING POLE, FISHING LINE AND FISHEYE CAMERA

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ABSTRACT: Visual inspection is currently the major approach to evaluate the structural condition of a bridge. Some researchers have done good work on applying special inspection vehicles and robot arms to increase the efficiency and reachability of inspection process. However, such heavy equipment is highly restricted in working space and is hard to deploy. In this research, we designed and implemented a portable device to facilitate the inspection. The proposed system is lightweight (approx. 350g), including fisheye lens, a camera and a transmitter for real-time transmission of inspection data. We rig the system using a fishing pole. This cable-based design greatly reduces the weight of the inspection system, allowing inspectors to carry and deploy the device easily. A software system, which can control the motion of device and process the vision information gathered from the camera, was also developed for a laptop computer. The proposed system is expected to replace and enhance current bridge inspection methods.

Keywords*: Bridge Inspection, Portable Device, Real-time Vision, Fisheye Camera*

1. INTRODUCTION

Bridge inspection is a critical task to ensure the safety and serviceability of bridges. In the U.S., the frequency of bridge inspection is set to 2 years interval in general [1], older bridges may need to be monitored more frequently. In Taiwan, inspection for steel bridges is crucial due to the hot and humid climate [2]. In state of practice, most inspections mainly rely on visual inspection [3]. Inspectors are sent beneath the bridge either by means of an inspection vehicle or temporarily erected scaffolding [4]. This not only is labor-intensive and time-consuming, but also poses threat on inspectors' safety [5]. Furthermore, the accuracy of evaluation result varies according to the knowledge, experience and diligence of inspectors [5]. Researches have been conducted on the solution of applying robot arms and vision systems for replacing human works [6-7], some with machine vision technique to enhance robot arm performance [8]. However, these approaches have a major drawback on flexibility. To reach deeper beneath a bridge, the robot arm applied needs to be heavy in order to support its own weight, and thus needs a firm and solid support structure, e.g. a special designed vehicle with outriggers. As a result, the whole inspection system is heavy and tardy; operations can be done only on relatively larger bridges, and the equipment cost will be very high. In this research, we propose an inspection system featuring the use of cables. Cables can carry much more load then the weight of itself, thus can extent to a considerable length without making the system weighty. The maximum weight of a complete digital camera system is less than 2 kilogram; a lightweight camera is only around 350 gram. Therefore, we can highly reduce the weight of an inspection system compared with former approaches, making it easy to be carried and deployed. In the research, we aimed at developing a robust methodology for optimizing system performance. A prototype system was assembled to test the feasibility of proposed methods. Fishing lines was used because it is very lightweight and tough.

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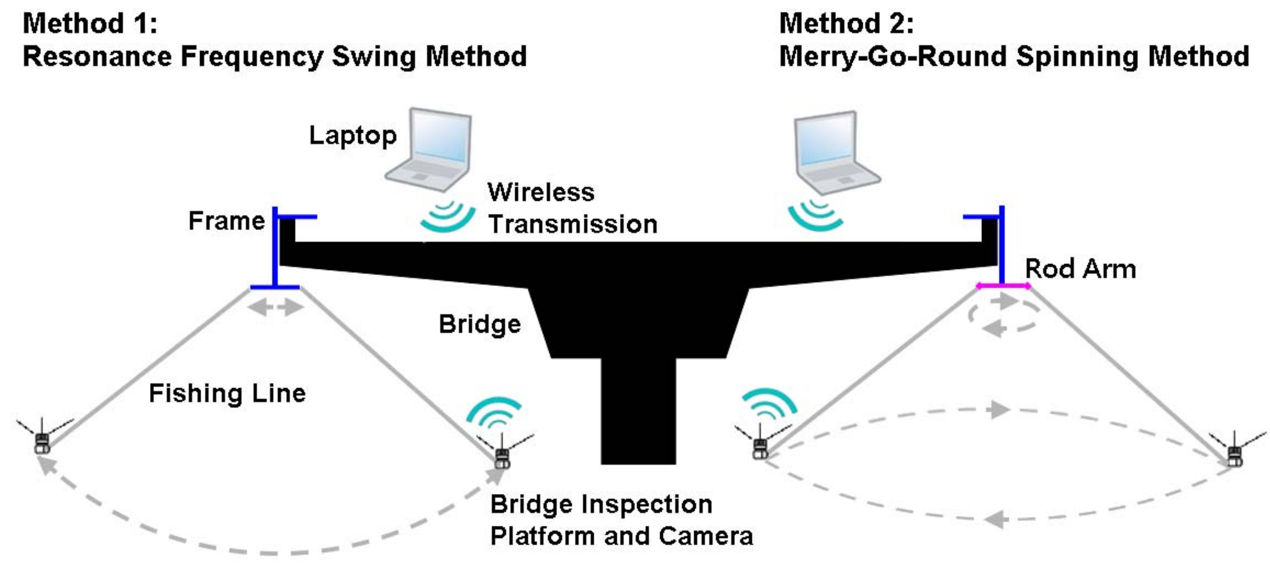

Fig. 1 Two types of bridge inspection methods

2. IDEAS

In this research, we developed two types of methods to operate the lightweight cable based bridge inspection system. These two methods are illustrated in Fig. 1.

Method 1: Resonance Frequency Swinging Method

The first method is called "resonance frequency swing method". A motor is set to create small reciprocating motion on the top of the fishing line. Inspectors can adjust the motor to make the motion cycle match to the frequency of fishing line length. Once the cycles are matched, the swing amplitude will gradually increase. Therefore, with small power motor the system can create large swing amplitude. The large amplitude can send digital camera to the deeper location beneath the bridge. Because the fishing line is longer than 3 meters, the system swinging cycle would be long; in other words, the camera will not swing too fast. Bridge inspectors can adjust the length of the fishing line and motor speed to achieve suitable amplitude.

Method 2: Merry-Go-Round Spinning Method

The second method is called "merry-go-round spinning method". This method attaches the fishing line to a small length rod arm. Inspectors can adjust the spinning speed to obtain different amplitude of the camera. Higher speed would lead to larger amplitude, and vice versa. By adjusting fishing line length and spinning frequency, inspectors can achieve suitable amplitude**.**

Discussion of Two Methods

First, the "resonance frequency swing method" can achieve larger inspection area. The "merry-go-round spinning method" needs considerably large horizontal space for spinning thus the cable length is limited. Next, the "merry-go-round spinning method" can provide better camera stability, i.e. we can make camera always looks up without attach another servo or motor. The "resonance frequency swing method" needs to attach additional servos to adjust the direction of the digital camera. It is still a better way to use additional servo to adjust camera direction by remote control in both methods. The camera moves faster in merry-go-round spinning method, therefore the camera needs shorter exposure time.

Both these two methods use fishing line as support mechanism. The fishing line only has tension force so it can carry heavy objects in an efficient way.

3. PROTOTYPE OF BRIDGE INSPECTION PLATFORM

The bridge inspection system needs a platform to collocate all the necessary devices such as servo, digital camera, wireless transmission module and batteries. The prototype of bridge inspection platform we developed is shown in Fig. 2. The total weight of the platform is only around 350 grams.

Hardware:

The platform consists of one control board, one Bluetooth module, one radio transmission module, one 180 degree servo, one fisheye camera, one battery and two ultrasonic distance sensors. The main hardware components are Innovati company products. The servo can allow inspectors to adjust camera direction and let the lens facing the bridge bottom. Top ultrasonic distance sensor is used to measure the distance between the platform and bridge bottom, Bottom ultrasonic distance sensor can measure the clear distance below the platform and ground. The distance information can help inspectors to prevent collision between the device and the bridge or other objects. The servo and ultrasonic distance sensors are controlled by the control board, which uses Bluetooth to communicate with laptop computer. The platform uses radio transmission module to send camera image back to laptop.

Software:

We use Microsoft Robotics Developer Studio (MSRDS) as the software platform. The control program is developed with Visual Programming Language (VPL) and is illustrated in Fig. 3. In this research, we use C# as the program language to develope a “Bridge Inspection System Service” which can control the Innovati hardware components in VPL through Bluetooth communication. The control program can also acquire ultrasonic distance sensors’ reading.

4. FIELD EXPERIMENT

We have finished the first step of field experiment. The setup of bridge inspection system is shown in Fig. 4. Besides the bridge inspection hardware platform, there are also a laptop computer, a radio transmission module (for camera image transmission) and a 12V battery. The laptop computer can display the camera image instantly and communicate with the hardware platform by the input of a gamepad. Bridge inspectors can easily adjust the camera direction base on real-time monitoring the swinging motion.

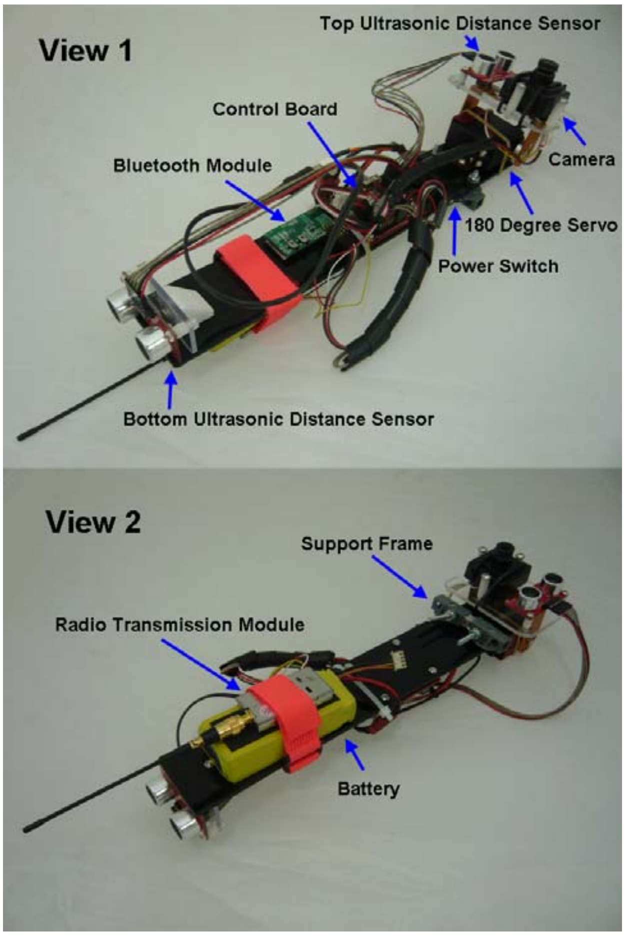

Fig. 2 Prototype of bridge inspection platform

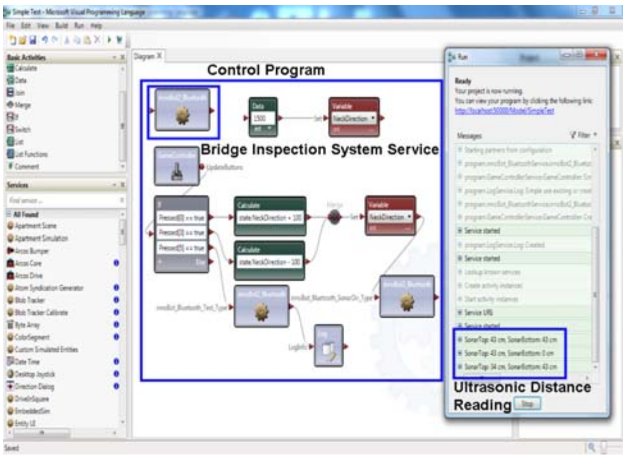

Fig. 3 The control program of bridge inspection system

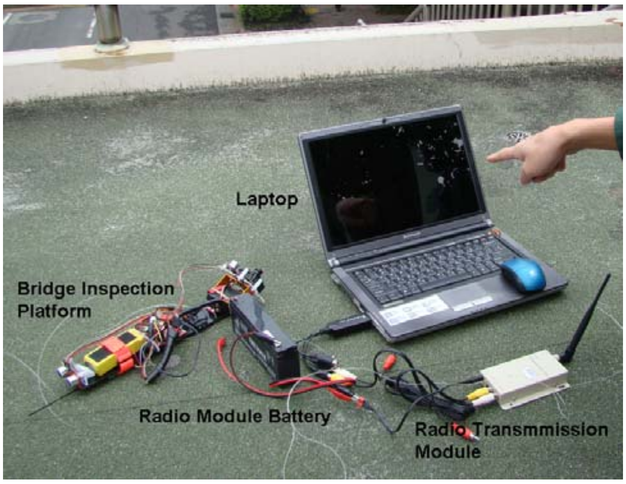

Fig. 4 Field experiment

Before the development of the swing mechanisms, we recruited two students from a local university to swing the platform manually. The experiment situation is shown in Fig. 5, and the inspection image gathered by camera is shown in Fig. 6.

Fig. 5 Field experiment

Fig. 6 Camera image of swing method experiment

During the field experiment, we found that the radio transmission was not stable enough. If the hardware platform moved too fast, the camera image would contain a lot of noise signal. A better digital camera may be the only solution to obtain clearer bridge inspection images. However, current technology does not allow a high-class digital camera to be lightweight. We hoped that the total weight of future bridge inspection system can be less than 2 kilogram. Lighter weight system can be moved and controlled easier.

5. CONCLUSION AND FUTUREWORK

The goal of this research is to develop a lightweight bridge inspection device and operation methodologies for replacement of current methods. We developed a prototype system of the proposed method. The system hardware platform contains ultrasonic distance sensors, digital camera and servo. The servo can move 180 degree and adjust the camera to face suitable direction. The system uses one laptop as a computational platform. Therefore, the control signal and camera image are centralize in the laptop with wireless transmission.

We developed two methods to move camera into bridge bottom: 1.) resonance frequency swing method, and 2.) merry-go-round spinning method. Both methods use small energy to generate large swing amplitude, and large swing amplitude can send the inspection device to the deeper part beneath the bridge. Our field experiment had verified the feasibility of the first method.

This research is still at the beginning stage. The quality of bridge inspection image still needs improvement. We generate the swing motion of the inspection platform manually. In the near future, we will develop suitable mechanism to swing the platform automatically. After we improve the support frame of the platform, we will implement the two proposed operation methods. The improved bridge inspection device should be less than 2 kilogram and can be easily deployed and controlled by only 2 inspectors. With the use of this lightweight cable based bridge inspection system, we believe that bridge inspection can be more efficient, low-cost and flexible in the future.

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