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Condition assessment of bridges based on unmanned aerial vehicles with hybrid imaging devices

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ABSTRACT

Bridge inspection and condition assessment using unmanned inspection equipment consisting of unmanned aerial vehicle (UAV) and hybrid imaging devices (e.g., CCD cameras, infrared cameras, etc.) has received considerable attention because of its several attractive features such as high safety and reliability as well as cost effectiveness. However, it has many challenging issues to be addressed for practical applications; for example, localizations of a UAV under the bridge, long flight time and stable flight near the bridge under the strong wind, and high-resolution image capture of cameras mounted on flying UAVs. In this paper, it is briefly explained how to address the challenging issues of the existing UAV-based methods by describing a recently launched research project of bridge inspection and condition assessment using UAVs.

1. INTRODUCTION

Aging of bridges is one of the most serious concerns in the developed countries such as the United States, Japan and Europe. For example, a quarter of total bridges in the US are structurally deficient and they need repair or strengthening and a half of total bridges in Japan get more than 50 years old in about ten years. Even though Korea is a relatively newly developed country compared to the previous two countries, bridge maintenance became an important task to the government as well as bridge engineers.
In order to secure the public safety and improve the structural reliability, bridge maintenance consisting of inspection, condition assessment and performance grading should be performed properly.

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Bridge structures have suffered from various damages such as crack, corrosion, efflorescence and exfoliation during its lifespan. Thus, they should be diagnosed at appropriate intervals. Of many inspection methods, visual inspection is most widely used, but it heavily depends on the experience of the inspectors (so it is subjective), and it is time-consuming, labor-intensive, costly, disruptive, and even unsafe for the inspectors.

Bridge inspection through the eye of the inspector can be replaced with digital image processing using various imaging devices such as CCD camera and infrared camera. It can be an alternative method to visual inspection because some limitations of visual inspection can be addressed, but most of the limitations of visual inspection still remain. Those are the difficulty issue in accessing for capturing images of a bridge structure, the safety issue of the inspectors, and the disruptive issue such as lane closures and traffic guidance. To resolve the abovementioned remaining problems, a totally new approach may need and an unmanned and automated approach such as the combination of unmanned aerial vehicles (UAVs) and imaging devices can be one of the most promising candidates.

In recent years, there has been a growing interest in bridge inspection using UAVs in many countries such as the United States, Japan, Europe, Taiwan and Australia since it can provide the close detail that is necessary for a thorough and reliable inspection. Moreover, it is known to be both safe and cost-effective; on the other hand, it is still considered to be in the primitive stages. It has many challenging issues to be addressed for practical applications. First, localization of a UAV under the bridge is one of the major concerns because GPS cannot be used in that zone. Next, for stable bridge inspection, longer flight time and more stable flight near the bridge under strong wind are needed. Also, it is difficult to capture high-resolution images when a camera is mounted on the flying UAV. Sometimes, vision cameras cannot differentiate real cracks from false cracks. This false alarm issue is also one of the challenging problems of the UAV-based bridge inspection approach.

This paper briefly describes the UAV-based bridge inspection and condition assessment approach by introducing a recently launched research project being performed by a consortium of 4 universities, 2 research institutes and 3 companies in Korea. Also, it explains how to address the challenging issues of the existing UAV-based methods.

2. RESEARCH TOPICS OF BRIDGE INSPECTION USING UAVS

A research project related to UAV-based bridge inspection and condition assessment financially supported by the Korean government was launched in 2016. The final goal of the project is to develop a rapid diagnosis and assessment method for bridges based on unmanned inspection equipment consisting of UAVs and imaging devices. To this end, the UAV is improved for more effectively inspecting exterior surfaces of a bridge and the ground control station is also developed for operating and remotely controlling the UAV. The noncontact inspection techniques based on the data fusion of hybrid images obtained from various types of cameras (e.g., CCD, infrared (IR)

or hyperspectral cameras) are developed as well. Finally, the rapid diagnosis and condition assessment techniques using the quantified data is developed.

It is briefly explained how to address the abovementioned challenging issues of the existing UAV-based methods in the on-going research project. First, the most prominent technical challenge is to estimate the location of a UAV in a GPS shaded area (i.e., under the bridge). To do this, a graph-based location estimation algorithm (or the SLAM (simultaneous localization and mapping) algorithm using graph structure) was developed in the project and it was verified in an external environment. Currently, the technique is being upgraded to minimize errors. Fig. 1 represents the block diagram of the developed localization algorithm.

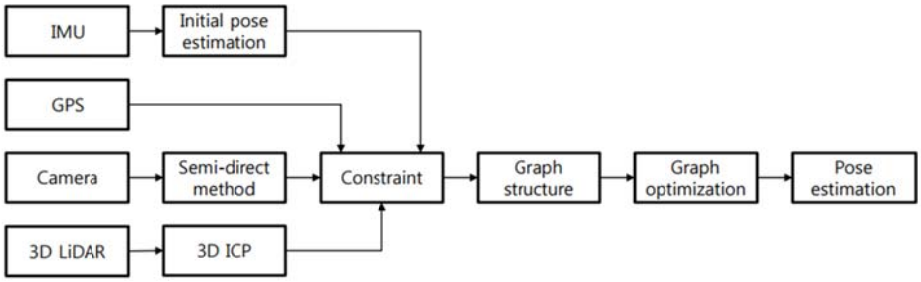


Fig. 1 Graph-based SLAM algorithm (developed by Prof. H. Myung (KAIST))

Next, the improvement of the UAV's performance is being carried out to optimize bridge inspection. First of all, it is trying to extend the flight time of the UAV to complete the inspection for at least one span at a time. In addition, a path following algorithm under strong wind is being developed because strong winds or gusts are likely to occur around the bridge. Also, the camera installation position is adjusted and a gimbal with 180 degree vertical rotation is designed to match the bridge inspection.

One of the most important tasks in UAV-based bridge inspection is to acquire high-resolution images using various imaging devices. In this project, it is trying to detect the damage that is difficult to grasp accurately through new imaging devices and to minimize the false alarm through the fusion of hybrid imaging devices. In other words, it is necessary to precisely detect the efflorescence on the surface of the concrete bridge by hyperspectral camera or to quantify the film thickness and corrosion on the surface of the steel bridge through IR camera. In addition, through fusion of CCD and IR cameras, cracks can be accurately detected without false alarms. Moreover, techniques to detect various types of damage such as exfoliation and bolting-loosening are also developed in the project. Fig. 2 describes a developing crack evaluation technique based on hybrid scanning image from CCD and IR cameras. Fig. 3 shows the preliminary field test and the interim results of crack detection on the surface of a concrete bridge.

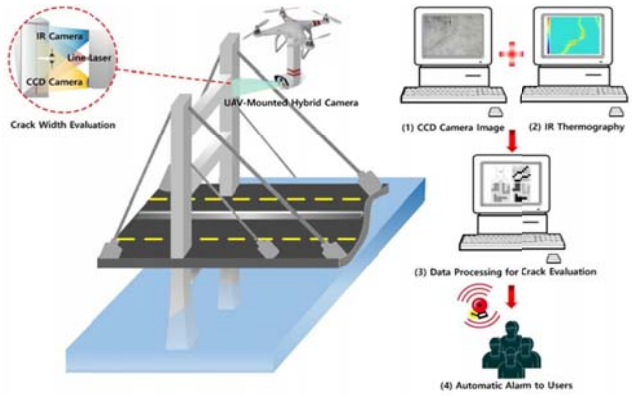
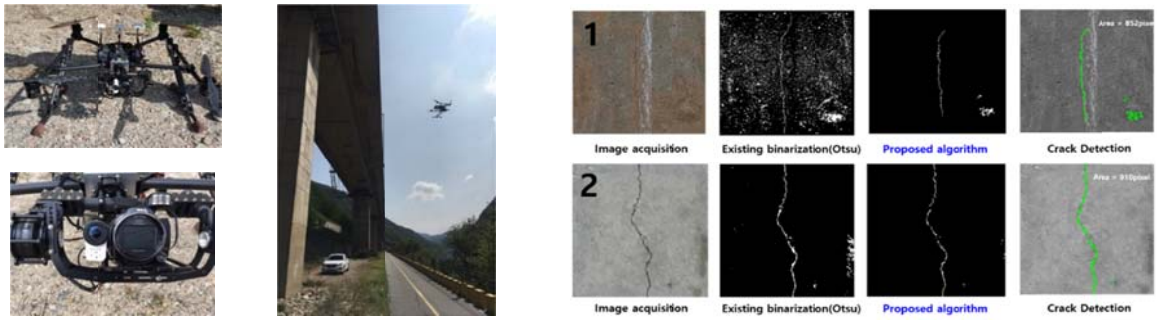


Fig. 2 Crack evaluation technique based on hybrid scanning image from CCD and IR cameras (developed by Prof. Y.K. An (Sejong Univ.))



(a) Developing UAV (b) Field test (c) Interim results of crack detection

Fig. 3 Preliminary field test (Lee *et al* 2017)

Finally, it is investigated to quickly assess the condition of the bridge through quantified damage information in the project. Based on the information obtained through UAV with imaging devices, a technique for automatically expressing the damage map of some parts or members of a bridge (e.g., bottom surface of bridge deck, exterior surface of girder and pier) is being developed. Also, this project is going to suggest a way to determine the condition grade of the bridge by considering the data from the existing bridge management system (BMS) as well as the data from UAV-based approach. In addition, an operational guideline for bridge inspection using UAV will be also established.

3. CONCLUSIONS

UAV-based bridge inspection and condition assessment is being a hot topic in the field of bridge engineering. This paper deals with some challenging issues in this research topic by considering the recently launched relevant research project in Korea, which is developing a new bridge inspection and condition assessment method using UAV with hybrid imaging devices such as CCD, IR, hyperspectral cameras. The detailed strategies to settle the challenging issues (e.g., graph-based SLAM algorithm, hybrid scanning image-based crack evaluation) and some interim results are presented.

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