Structure Safety Inspection System Using Multiple Sensors and PTZ Camera

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***Abstract*—In recent years, those aging buildings such as the high-rise buildings and the chemical plant structures generate many social and economic issues due to crack, fire and collapse. Furthermore, these social and economic issues will lead to national loss. The aforementioned problems cannot be resolved through human eye or human power. This thesis proposes the structure safety inspection system using a small aircraft equipped with multiple sensors in order to address these problems. This small aircraft saves and manages the data obtained through the structure inspection and also provides efficient information. The purposes of this thesis are to synchronize, save and manage multiple sensor data, video and thermos graphical data that are transmitted from a small aircraft and also to implement the safety inspection integrated management system that provides inspection results and history information.**

***Keyword*— Multi-Sensor, Small Flying Vehicles, Sensor Fusion, Monitoring System, PTZ**

I. INTRODUCTION

Recently, as outdated high-rise buildings, bridge piers, wind power generators, petro-chemical plant structures are deteriorated, a lot of problems for the dangerous situation such as internal/external cracking, fire and disasters are taken place and create a social issue. In order to detect dangerous situations and cracking, there is a small flying vehicle that does the work that is hard to be inspected by the workers as a proxy. This small flying vehicle mounted with various sensors provides a function of integrated management services from structure monitoring to safety inspection. A process of developing small flying vehicle and verifying its performance for safety inspection of structures is continuity of complicated process from its design to test flight and a lot of cost and research time are required. In order to perform safety inspection for the structures, mounted various sensors are required to be measured and measured result is required to be transmitted. This study intends to suggest efficient wireless transmission, control technique for sensor data including sensing space of sensed data, data accumulation and its transmission.

This study intends to design integrated management system for safety test that stores and controls multiple sensor data, image, thermal infrared image, and data being transmitted from small flying vehicle through its synchronization and provides test result and historical data information.

II. PROCEDURE FOR PAPER SUBMISSION

Various sensors, imaging equipment and communication equipment are mounted on unmanned small flying vehicle. Data obtained from mounted various sensors and devices will be controlled and information provision service will be researched [1,2].

A. Review Stage Type of sensor

TABLE 1. Kinds of sensors

		
CO Sensor	VOC Sensor	Dust Sensor
		
Ozone Sensor	CO2 Sensor	Humidity sensor

Temperature sensor is a device used for recording or controlling temperature by detecting temperature of fluid such as air or water or wall. Detected temperature is converted to electric signal and transmitted [3].

Humidity sensor is a device that detects humidity and outputs such humidity as electric signal. This sensor uses a mechanism that electric resistance and its capacity of porous ceramics and polymer electrolyte are changed due to physical absorption of moisture.

CO sensor is a sensor used for detecting carbon monoxide. In our living environment, dangerous gases of numerous types exist and recently, gas-related accident in ordinary homes, business places and construction sites, explosion accident in petrochemical combine, mines, chemical plants and pollution,

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contamination are taken place in a row. As it is almost impossible for human sensory system to quantify concentration of dangerous gas or discriminate its type, gas sensor that uses physical, chemical properties of substances is used for detecting gas leakage, measuring its concentration and warning dangerous situation.

CO2 sensor is a device for measuring carbon dioxide. Most common principle of CO2 sensor is NDIR and chemical gas sensor. Measuring carbon dioxide is important for monitoring indoor air quality and various industrial processes.

Ozone sensor is a device for measuring ozone concentration in atmosphere. Dust sensor is a device for detecting floating dust or number of condensation nucleus.

VOC sensor is a device for evaluating air quality based on the amount of volatile organic compounds –cigarette smoke, harmful smoke and odour being generated at the time of cooking, outside pollution source, pollution source of living organisms [4].

B. Final Stage Structures that require safety test by small flying vehicle

TABLE 2. Diversified structures that require safety test

	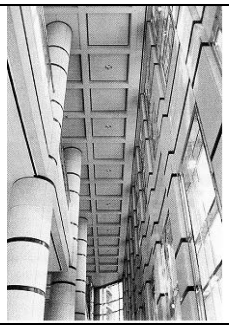
a. High-rise building	b. Building inside
	
c. High smoke stack	d. Chemical plant
	
f. Cultural property	g. Wind power generator

Table 2 is an illustration of diversified structures [5]. a. At the time of constructing high-rise building, safety problem is required to be inspected and for outdated high-rise buildings, efficiency of service life extension is provided by detecting cracking and abnormal temperature by its deterioration, b. By detecting cracks of building inside, building safety is increased, c. By monitoring cracking and dangerous elements of cultural property, national waste could be reduced. Recently, due to frequent fire in chemical plants, safety is required in reality, d. f. By analysing, investigating cracking and emission gas in internal/external walls of plant smoke stack and chemical plants in real time, an advantage of being able to prevent an accident in advance is provided. In addition, site application for external cracks inspection through cinematography and internal cracks inspection through thermal infrared camera for the blades and tower of wind power generator that is popular as a renewable energy source will be performed and safety inspection manual for wind power generator is under the process of R & D.

C. PTZ(Pan Tilt, Zoom) Camera

Format and save your graphic images using a suitable graphics processing program that will allow you to create the images as PostScript (PS), Encapsulated PostScript (EPS), or Tagged Image File Format (TIFF), sizes them, and adjusts the resolution settings. If you created your source files in one of the following you will be able to submit the graphics without converting to a PS, EPS, or TIFF file: Microsoft Word, Microsoft PowerPoint, Microsoft Excel, or Portable Document Format (PDF). GWP is a scale of evaluating how much heating effect of gas of 1kg is for a certain period of time after greenhouse gas is emitted in the atmosphere when comparing it with carbon dioxide of 1kg. In case of assuming CO2 as 1 based on 100 years, CH4 is 21, NO2 310, HFCs 1,300, PFCs 7,000 and SF6 23,900, respectively [3]. The location information of camera consists of the coordinates to represent the current location of moving objects and structures, the coordinates to represent the location of camera and the distance, height difference and angle between the objects.

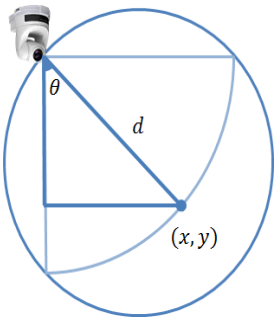

Fig. 1. Location Information of Camera

Fig. 1 is the location information of camera.

The location information of an object consists of the coordinates to represent the current location of a moving object, the coordinates to represent the location of a camera and the distance, height difference and angle between the objects. The location value of camera will not be changed once it is installed. The location of a moving object continues to change; thus, the distance, height difference and angle value between a camera and a moving object shall be calculated based on the pre-defined formula for the two coordinates.

The moving object (x, y) and angle determines the horizontal rotational direction (θ) of a camera, whereas the distance (d) between objects determines the enlargement and reduction magnification of a camera. In addition, the height difference of a camera determines the vertical rotational angle of a camera [6].

It is required to control the operation of horizontal rotational angle, the vertical rotational angle and the

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enlargement/reduction value for PTZ camera. [7]

The operation signal of a camera requires a conversion between those coordinates and Cartesian coordinates. It is also necessary to have the coordinates (M_x, M_y) of a moving object calculated on the orthogonal coordinate plane and the location coordinates of a camera (C_x, C_y). It is possible to obtain the distance difference between two points d_{xy} through Formula (1) by utilizing the two coordinates.

(1) $d_{xy} = \sqrt{d_x^2 + d_y^2}$, $d_x = |M_x - C_x|$, $d_y = |M_y - C_y|$

It is required to calculate the horizontal rotational angle of 360 by using Formula (2) for 360 degree system by converting the reference coordinates into the polar coordinates that uses the location coordinates of a camera as the starting point.

$$\theta_p = \begin{cases} \tan^{-1}(\frac{Y}{X}) & X > 0, Y \geq 0 \\ \tan^{-1}(\frac{Y}{X}) + 360^\circ & X > 0, Y < 0 \\ \tan^{-1}(\frac{Y}{X}) + 180^\circ & X < 0 \\ 180^\circ & X = 0, Y > 0 \\ 270^\circ & X = 0, Y < 0 \end{cases} \quad (2)$$

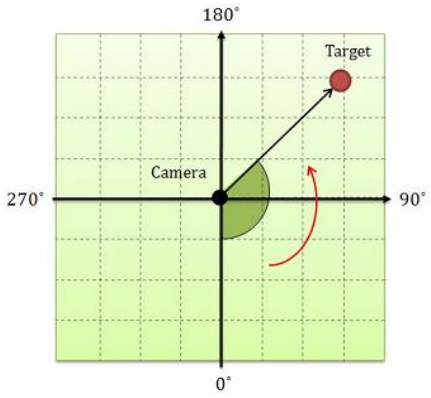

Fig. 2. Scope of horizontal rotation

The scope of horizontal rotational angle θ_p of a camera is $0^\circ \leq \theta_p \leq 360^\circ$.

As for the vertical rotational angle of a camera θ_t, the height relative to the surface from the installation point of a camera is h_c, whereas the height of a moving object is h_m. They can be obtained through Formula (3).

$$\theta_t = \cos^{-1}(\frac{h}{\sqrt{d_{xy}^2 + h^2}}), h = |h_c - h_m| \quad (3)$$

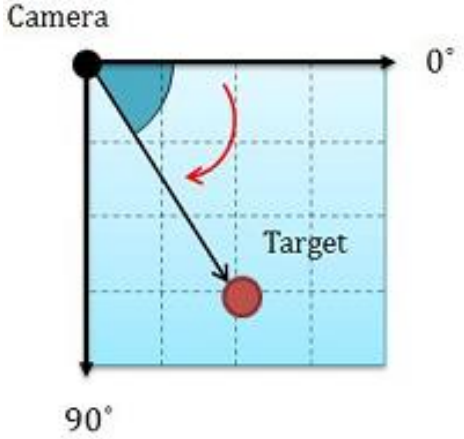

Fig 3. Scope of vertical rotation

The scope that the vertical rotational angle θ_t of a camera can have is $0^\circ \leq \theta_t \leq 90^\circ$.

The reliability of operation control value of PTZ camera for the operation control of a camera will increase with a higher degree of accuracy for the process of obtaining the location of an object.

III. CONTENTS AND METHOD OF STUDY

There are various sizes, heights and shapes in relation to the structures. It is difficult for a small aircraft to approach at short ranges in terms of detecting crack or risk factors when accessing to a structure. PTZ camera is useful as a camera to be installed on a small aircraft to detect the location of cracks in a structure because it can be enlarged and also it is able to move to left and right. Moreover, such functions of PTZ camera as pan, tilt and zoom can be utilized in order to detect crack and risk factors when a subject is at a remote location.

A. PTZ Module of Video Camera

It is possible to examine in more detail a structure by conducting PTZ control of a video camera in order to conduct visual inspection of a structure that is hard to access from a short distance.

It is possible to shoot a structure in a wide area with 355° at left and right and 120° at top and bottom of PTZ camera. It is also possible to recognize an object at up to 30M in dark nature or at night with the function of IR camera.

The screen of PTZ camera is set at 200 million pixels. The problem associated with blind spot when conducting horizontal and vertical rotation and enlargement/reduction operation can be solved.

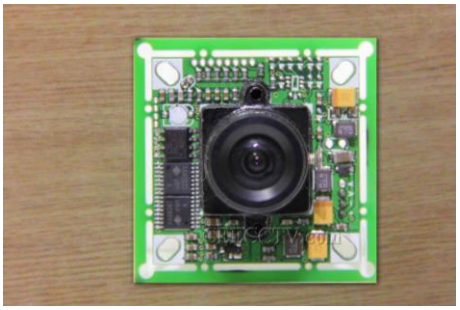

Fig. 3. PTZ camera of video camera

Fig. 3. shows PTZ camera that is able to detect high-rise buildings and places that cannot be detected by human eyes because it is equipped with a small aircraft.

Fig. 4. Small aircraft equipped with multiple sensors

Fig. 4. Shows a small aircraft equipped with multiple

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sensors. It examines the safety inside and outside a structure through multiple sensors and video sensors.

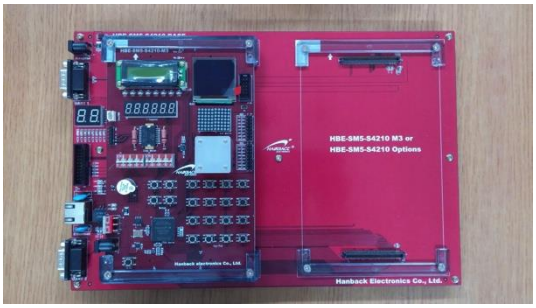

Fig. 5. Multiple sensor module embedded system

Fig. 5. is the embedded module that processes and analyses the sensors of various types installed in a small aircraft. Currently, the research project that focuses on the transmission protocol and sensor data monitoring system to receive various signals is in progress based on the embedded system to receive the signals of sensors. At present, it is the monitoring system that measure carbon dioxide in the air using CO2 sensor and sends signals when the amount and proportion of carbon dioxide are high.

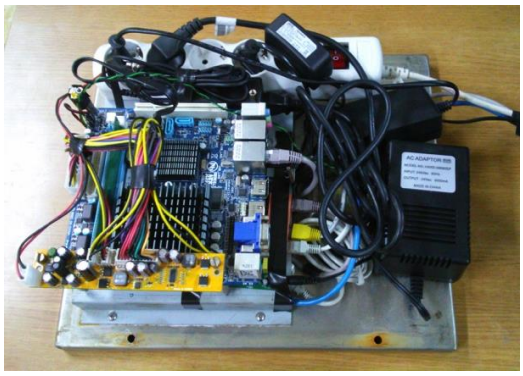

Fig. 6. Structure safety inspection integrated management system based on a small aircraft

Fig. 6. shows the structure safety inspection integrated management system based on a small aircraft. It consists of power supply unit, web server and Wi-Fi based wireless video transmission system to perform the function of storage server.

It is the low-power video management server system based on an embedded system that combines, saves and manages multiple sensors and PTZ camera. As for videos, those videos transmitted in motion JPEG encoding are synchronized in accordance with the time. Upon request of users, the sensing data and videos are also synchronized and transmitted.

B. Design of multiple monitoring system

Multiple sensor monitoring system is a system for preventing occurrence of cracking and various dangerous situations due to diversified causes including deterioration or defective work of structures in advance. In addition, this system inspects data in the air in real time using unmanned flying vehicle and by using obtained data, monitors subject structure in real time.

Multiple sensor monitoring system is mainly divided into small flying vehicle and embedded system. Small flying vehicle is an unmanned flight system that performs data detection and transmission in real time by using multiple sensor and embedded system receives data transmitted from small flying vehicle and processes received data in real time and at the time of risk occurrence, informs users of dangerous situation through smart phone.

As embedded system that is data processing system is required to process data collected by heterogeneous multiple sensors based on processing module that may process data in real time with high speed and perform a function of processing images in real time at the same time, it was designed based on excellent performance. In addition, as sensors being used for multiple sensor monitoring system use diversified sensors including PTZ camera having a function of infrared ray, temperature, humidity sensors, it is required to use and provide diversified interfaces.

Embedded system provides a function of acquiring, processing and transmitting various sensor data and controlling sensors by analysing instructions after receiving it and provides monitoring information of sensors so that status information of each sensor could be observed remotely. At the same time, in order to synchronize data collected by each sensor, it provides a separate function and a process of storage, transmission processing of sensor data is required.

C. Structure of Multiple Sensor Monitoring System

The whole configuration diagram of the system proposed in this paper is shown on figure 7.

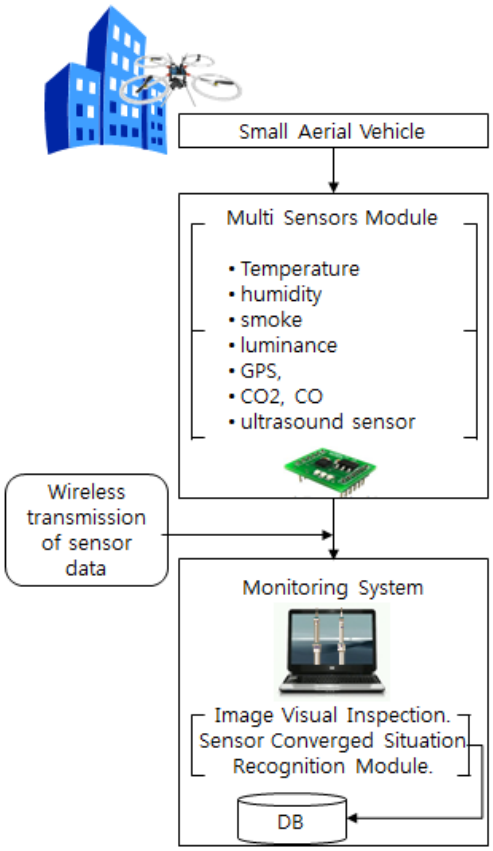

Fig. 7. System Configuration Diagram

As main function of multiple sensor monitoring system is that the functions such as high speed input/output processing of various sensors, real time synchronization of sensing data, transmission of processed data are required to be performed at the same time, real time monitoring is required. By flight of

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small flying vehicle, each sensor starts to be operated and at this time, storage of sensing data and its transmission module are required. In addition, this system was designed to transmit and store collected data in big data storage device and process stored data after the flight is finished.

Each module of multiple sensor monitoring system was designed to perform each function that is required to be provided by data processing system. In order to process image data of PTZ camera, compression module is provided and for data synchronization of various sensors, synchronized module and transmission module for transmitting data in real time are provided. In addition, in order to process input/output of diversified sensors being connected through each interface, temporary storage space was provided. These modules provide informing and monitoring system function through smart phone by it being implemented in parallel.

IV. SENSOR CONTROL AND DATA PROCESSING

A. Sensor Control

Multiple sensor monitoring system provides real time control function to multiple sensors. As this system uses operating small flying vehicle and commanding embedded system, multiple sensor monitoring system provides control function to diversified sensors. This system controls sensors by transmitting instructions to sensor that is desired to be controlled and using data processing system that analyses transmitted instructions.

B. Data Processing

In multiple sensors monitoring system, sensing data collected by each sensor is processed in real time and transmitted to embedded system. However, as transmission rate of transmission route being used at the time of transmission by embedded system is limited, in order to transmit big data, a process of compressing sensing data is required. In particular, as image data being collected by camera is big data, its compression process is essential and as compressed image data is also unable to be transmitted at one time, it is required to be transmitted to embedded system by dividing it into transmissible packet by using a separate transmission format. In addition, as data of each sensor is required to be transmitted by division at the time of transmitting sensing data, transmission format is required to be indicated with tag matching with each sensor. At the same time, tag of sensing data based on time synchronization is required to be included.

C. Video of PTZ Camera

It is required to fly a small aircraft and transmit the operation of multiple sensors and the data of PTZ camera to the integrated management system. The transmitted data can be verified through the monitor screen. It is possible to confirm the location immediately through GPS sensor and detect the crack and risk factors of a structure.

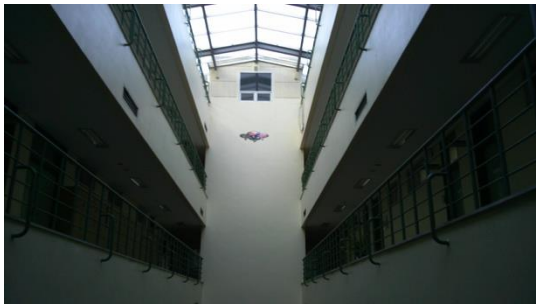
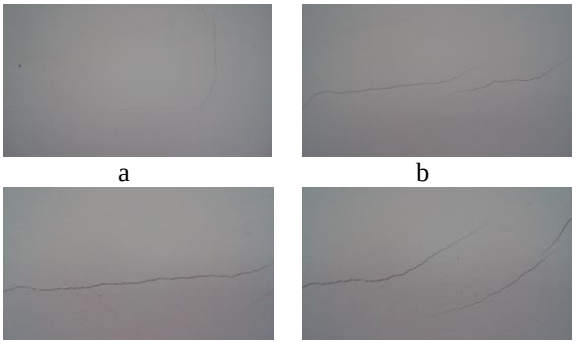


Fig. 8. Structure inspection of small aircraft

Fig. 8. shows how a small aircraft inspects a structure.



a b c d

Fig. 9. Cracked wall surface taken by a small aircraft

Fig. 9. is the conventional figure taken by PTZ camera of a small aircraft. b is the enlarged version by 2x zoom. c and d are the enlarged versions by 3x zoom. PTZ camera allows us to take pictures of wall surfaces located at a high-rise building and check them accurately and specifically.

V. EXPERIMENTAL RESULT

It is difficult to visually confirm the crack and risk of high rise buildings and high structures. They can be identified using PTZ camera equipped on a small flying object. In the existing method, the person may face with dangerous situation as the person should climb directly to the high rise building. With a small flying object, however, the location of cracks can be safely identified.

The places where the experiment was performed with a small flying object are the inside and outside of building 3 at the department of engineering, Sunchon University. And the experiments were performed 6 times. Even though the video was out of focuses by the shake during video shooting, relatively stable video could be acquired. 4 videos out of 6 were accurate and the location of crack were accurately identified with GIS sensor

Table 3 shows the result of experiment with a small flying object

TABLE 3 result of experiment with a small flying object

Number of experiment	Video acquired	Video accuracy
6 times	4	88%

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VI. CONCLUSION

At present, a lot of small flying vehicles are applied, researched and developed in various fields including shooting site of TV program such as entertainment and documentary, patrol purpose for safety control, exploration purpose for roving Mars and other purpose of diversified specificities.

This study is being progressed by using small flying vehicle for safety inspection of structures. By using small flying vehicle for safety inspection of structures, development process that may collect, store, transmit and process multiple sensor data of multiple sensor monitoring system was explained. In multiple sensors monitoring system, modules for high speed input/output processing, real time sensor data synchronization, compression, and transmission of data were designed.

This thesis focused on the use of a small aircraft for the safety inspection of a structure. This thesis described the multiple sensors and PTZ camera for the structure safety inspection. Also, it described the structure safety inspection integrated management system based on a small aircraft, which can collect, save, transmit and process data. As for the multiple sensors monitoring system, such modules as high-speed input/output processing, real-time sensor data synchronization, data compression and transmission were designed.

In the future study, a system that may increase utilization accuracy of various sensors through diversified direct tests by using various sensors and prevent structural cracking and dangerous situations in advance through analysis of image data being transmitted from PTZ and thermal infrared camera is scheduled to be researched.

It is expected that based on this system, various structures would be free from the danger of fire, disaster and deterioration and its high-levelled safety would be maintained with reasonable coast.

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