Flight Path Planning and Simulation for Exterior Inspection of a Dome-type Nuclear Containment Building Using UAV

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1. Introduction

A operating nuclear power plant is an important national infrastructure designed to be safe from natural disasters and accidents [1]. It has also a national radiation emergency response system to respond to emergencies such as the Fukushima nuclear accident. The response system after an accident is important, but periodic outward inspections to prevent accidents in advance are also important. One of the periodic outward inspections is visual inspection. However, visual inspection has difficulties to ensure the safety of inspectors and to overcome the blind spots. Recently, the technology of unmanned aerial vehicles (UAVs) has developed rapidly, enabling efficient visual inspection of dome-type operating nuclear power plant containment buildings with high resolution images. Therefore, this study conducted a dynamic simulation that establishes flight path, controls a UAV, and acquires images. The results show that a small UAV can efficiently acquire images for blind spots and high-altitude areas that are difficult to identify.

We adopted ~~a~~ the calculating coordinates method of ref. [2] to maintain a certain distance between the camera and the subject in order to read the magnitude of the damage from the images using UAVs. However, this method considers the safe distance between the UAV and the obstacles in all directions, so as the safe distance increases, the range of areas that cannot be photographed due to actual movement increases significantly.

In this paper, a flight path generating algorithm was established by using a dynamic simulator including the 3D model of a dome-type nuclear power containment building to be inspected and an external control program linked thereto was developed. After determining the image size and the horizontal and vertical moving angles of the UAV, moving points generation and path moving process were developed considering the morphological characteristics of a dome-type nuclear containment building~~s~~ and the safe distance . In addition, the autonomous flight control of the UAV acquiring images was simulated by linking the external control program with ~~a~~ the dynamics simulator.

2. Methods and Results

2.1 Flight path planning based on 3-D model in a dynamic simulator

In this paper, a flight path planning algorithm using a dynamic simulator including the 3D model of a dome-type nuclear power containment building to be inspected and an external control program linked thereto were developed. The image size calculation method and the horizontal and vertical movement angles of the UAV proposed in reference [2] were used. The safety distance from the structure to the UAV was set to 1.5m in consideration of the problem caused by the reaction of lift of the UAV. The UAV's movement path planning process was configured as shown in Fig. 1. The entire process was classified into the upper part of the dome and the lower part. It is assumed that the UAV always moves around the subject in a counterclockwise direction.

First, in the case of the lower part of the dome, a structure connected to the wall causes restrictions to the movement of the UAV. When the movement is restricted in the vertical direction which means the rooftop of the structure is recognized using the proximity sensor in the dynamic simulator, the process is configured to move the UAV horizontally before the UAV comes to the structure within the safe distance. In order to minimize the area that cannot be photographed due to path change, the camera was tilted by a specific angle to obtained the image of the subject. When the movement of the UAV in the horizontal direction was restricted, the UAV was immediately moved to the top waypoint at the corresponding position and then moved to the horizontal direction.

Next, in the case of the upper part of the dome, the UAV rotates around the dome in the x and y planes of the corresponding position with respect to the central axis of the dome. And the UAV goes up to the next level corresponding to the vertical moving angle. The camera is tilted downward by a specific angle. After the UAV passes all the waypoints, the images of the entire exterior surface of the dome are obtained.

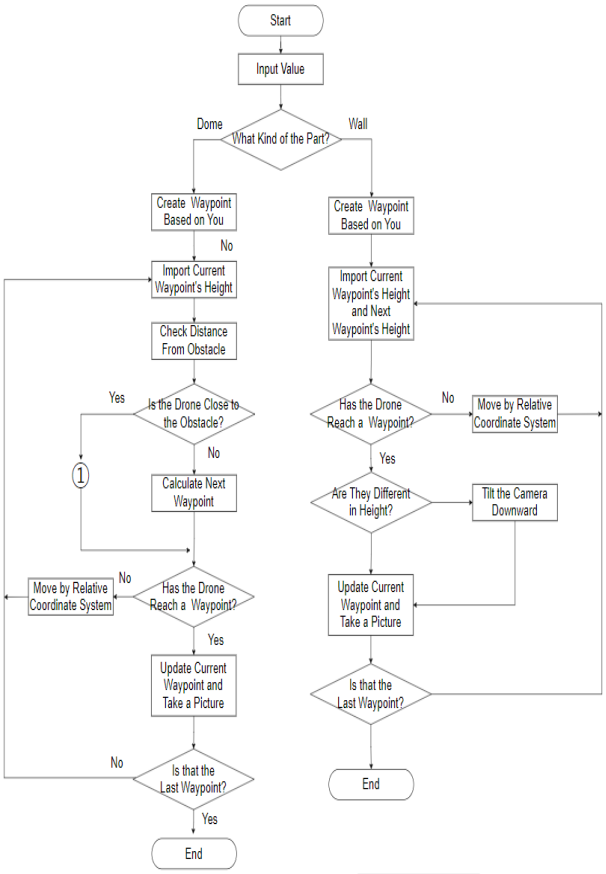

Fig. 1. Flowchart for flight path planning.

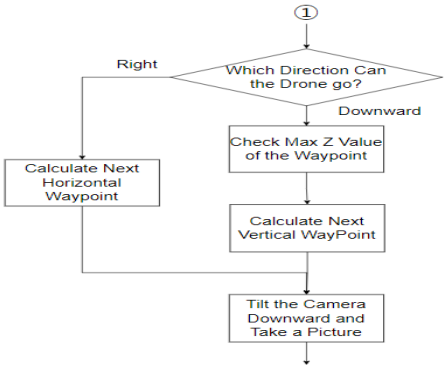

Fig. 2. Process for bypass routes

The external control program was developed to generate way points in the dynamic simulator according to the developed algorithm. By establishing the flight path according to the algorithm and displaying it within the simulator, it became possible to visually confirm the appropriateness of the flight path in real-time.

2.2 Flight Control Simulation

It is necessary to test in advance that the UAV can follow the flight path established in Section 2.1 and acquire images of each containment building section properly. The external control program commands the UAV in the dynamic simulator through TCP/IP communication to the exterior surface inspection simulation. The necessary basic data may be given through a user interface as shown in Fig. 3. Fig. 4 shows the flight path points indicated in the dynamics simulator and the UAV flying the given flight path.

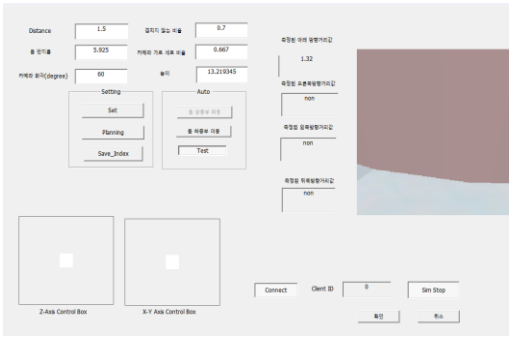

Fig. 3. User Interface

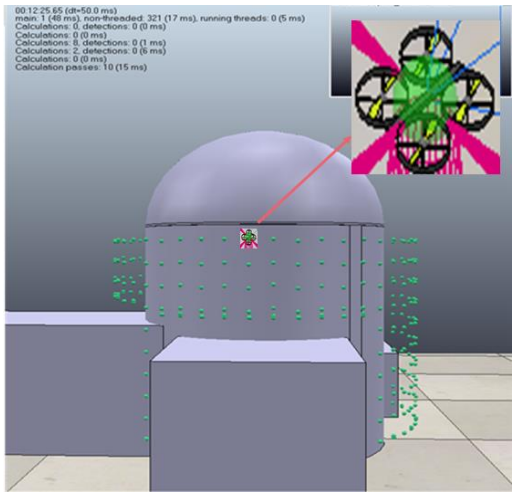

Fig. 4. Flight simulation

3. Conclusions

In this paper, the flight path generating algorithm of a UAV was developed by comprehensively considering the morphological characteristics of a nuclear containment buildings and the safety distance required for the UAV, and the external control programs were conducted to simulate exterior surface inspection of the dome with a dynamic simulators. In the case of the lower part of the dome, as the distance from the subject increases, a large area can be photographed at once with a small number of photographs times, but there is a problem that the photographing range is greatly limited due to adjacent structures. On the contrary, as the distance to the object decreases, it is estimated that the number of shooting photographs increases, and the uninspectable area decreases significantly. However, there may be differences between the simulation results environment and the real environments due to various factors, Additional research will be conducted through experiments using actual UAVs.

The research results of this paper can be applied to situations where visual inspection is difficult.

REFERENCES

[1] Seo, Jeong Moon, “Aging and Its effects on the Sensitivity of Containment Buildings”, KAERI/TR-1020/98, 1998

[2] Kim, Bong-Geun, “3-D Model-based UAV Path Generation for Visual Inspection of the Dome-type Nuclear Containment Building”, Proceeding of the 2016 Journal of KIBIM, 2016, pp. 1-8