Design of a Drone-Based Real-Time Service System for Facility Inspection

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***Abstract*—This paper presents the implementation of a drone-based business model dedicated to facility safety monitoring. The effectiveness of this system was demonstrated through its application in the inspection of a real structure with defects. The configuration of the business model for facility safety monitoring encompasses various components, including 3D modeling of structures, development of specialized drones for inspection purposes, Real-time video transmission of high-resolution 6K images utilizing 5G technology, artificial intelligence processing capabilities, and real-time monitoring based on static photographs. Special structures such as roads, bridges (piers), sports arena, and high-rise buildings pose challenges for human inspection due to safety concerns and accessibility limitations. By employing drones for safety inspections, we can significantly mitigate risks, reduce inspection costs, and save time. Furthermore, the integration of real-time image multi-streaming and artificial intelligence analysis allows for further time savings and improved efficiency. The implemented drone system was deployed and tested in a sports stadium, roads serving as a practical test bed for real-time application of the service model.**

Keywords— drone, modeling, streaming, inspection, facility

I. Introduction

The inspection of defects in facilities such as high-rise structures, bridges, piers, roads, and dams can be challenging and hazardous for humans. Attaching a high resolution camera to a drone is a convenient and effective method for facility safety monitoring that provides multiple benefits. Drones equipped with cameras can significantly enhance the safety of the inspection process while reducing both the time required for the inspection and associated costs. Additionally, drones can easily access and inspect hard-to-reach or hazardous areas that may be difficult for human inspectors to reach. By capturing high-quality imagery with the attached camera, drones can provide detailed and accurate assessments of the facility's condition. Drones offer a number of advantages over traditional methods of facility safety monitoring, including: (1)Safety: Drones can inspect facilities in areas that would be too dangerous for human inspectors, such as high-rise structures or hazardous materials sites. (2)Speed: Drones can inspect facilities much faster than human inspectors. (3)Cost-effectiveness: Drones are a cost-effective way to inspect facilities, especially when compared to traditional methods, such as helicopter inspections. The use of drones equipped with high-definition cameras provides a rapid and thorough inspection of a broad area, enabling efficient inspection. Furthermore, incorporating artificial intelligence(AI) technology into the inspection process can further enhance efficiency and reduce the overall time needed for the inspection. By analyzing data captured by the drone's camera, AI algorithms can quickly identify potential problems and highlight areas that require further inspection. In conclusion, combining drones with artificial intelligence technology is a powerful solution for performing efficient and effective facility safety monitoring. Overall, drones offer a number of advantages over traditional methods of facility safety monitoring. They are more efficient, safer, and can collect more data. As a result, they are becoming increasingly popular for a variety of inspection applications. In this paper, we designed a drone and drone-base business model for facility safety monitoring and evaluated the effectiveness of the business model. Our system provided an efficient and reliable solution for facility safety monitoring by utilizing drones equipped with high-definition cameras. The configuration of the business model for facility safety monitoring includes 3D modeling of structures, the design and development of drones specifically for facility safety monitoring, of 6K-resolution images using 5G technology, AI-based data processing, and real-time monitoring through static photographs. By utilizing 3D modeling, we can generate a detailed and accurate representation of the facility, which is essential for planning and conducting inspections. Our specialized drones, equipped with high-definition cameras, capture high-quality imagery of the facility, which is streamed in real-time over 5G technology. This data is then analyzed using AI algorithms, allowing for the quick and accurate identification of any issues or defects.

II. The Service Structure for Structural Defect Inspection

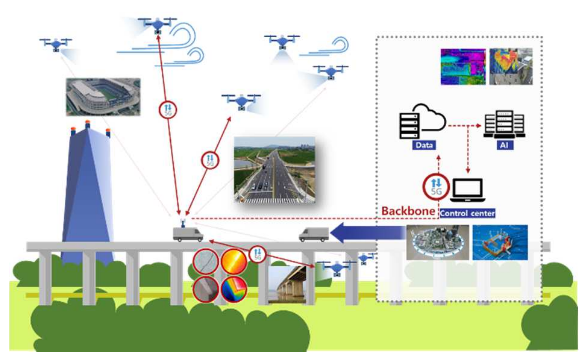

Fig. 1. A service framework designed for the inspection of facility defects.

Managing the safety of special structures such as roads, bridges, sports arenas, and high-rise buildings can be challenging for humans due to difficulty in accessing them and risks involved in inspections. The use of drones for safety inspections can result in reduced accidents, inspection costs, and time. Furthermore, by implementing real-time image streaming and AI analysis, it is possible to improve efficiency and reduce the amount of time needed for inspections. The following describes the functions of facility defect inspection using a drone. (1) The structure needs to be modeled in 3D so that it can be linked to an open map. (2) It is necessary to equip multiple drones with high resolution cameras capable of capturing images in 4K or 6K resolution. (3) The captured high resolution static photographs should be transferred to a mission computer (MC) for further processing. (4) The MC needs to utilize 5G network to transmit the high resolution images in real-time to a ground media server. (5) The ground media streaming server should multicast the high resolution images through a real-time streamer to both an artificial intelligence server and a monitoring system for artificial intelligence processing. (6) The artificial intelligence server must receive the high resolution static photographs streamed in real-time from the and conduct real-time defect inspection. (7) The real-time monitoring system should visualize multiple data points, including drone flight coordinates based on the open map, static photographs received from the live media broadcasting server, location coordinates obtained from static photograph EXIF data, and defect detection results provided by the artificial intelligence server [1].

III. A THREE-DIMENSIONAL MODELING BASED ON PHOTOGRAPHS

This chapter provides an overview of the process of generating three-dimensional models using image-based techniques. The approach involves capturing images of the piers, roads, and sports stadium from various angles using a drone. Multiple photographs were obtained by utilizing the drone's capabilities. These images were used as the basis for conducting image-based 3D modeling, as shown in Figure 2.

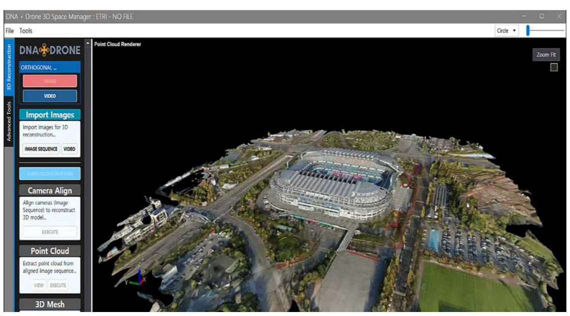

Fig. 2. A reconstructed 3D model of the sports stadium that has been created using real photographs.

The following outlines the actual method employed for image-based 3D modeling[2]: (1) Multiple images of the object were captured using drones. (2) Feature points were identified using algorithms such as SIFT or SURF. (3) Matching point pairs (inliers) were extracted using these feature points, representing valid matches. Outliers, or mismatched point pairs, were eliminated using techniques such as the RANSAC algorithm and epipolar geometry. (4) A camera matrix was extracted by analyzing the position and posture of the camera based on the geometric information derived from the aforementioned photographs. (5) A 3D point cloud was generated using the matching point pairs (inliers) and the camera metrics obtained from the previous steps. (6) The accuracy of the 3D points was enhanced through fine-tuning, employing bundle adjustment to reduce errors. (7) Optimized 3D meshes were calculated using the generated 3D point cloud. (8) Multiple photographs of the object captured by the drones were utilized to create a texture file (image file). (9) By applying the texture file onto the generated 3D mesh, a 3D textured object was created [2]. Figure 2 showcases a reconstructed 3D model of the sports stadium, which was generated through obtaining actual photos via drone.

IV. DESIGN A DRONE FOR FACILITY INSPECTION

To inspect a facility, a drone equipped with high-definition image capturing mission-specific equipment is a must. To seamlessly process artificial intelligence in real-time, a 5G mobile network communication module is required to transmit high-quality images to a ground-based artificial intelligence server [1]. The following are the functions and configurations of the drone specifically designed for facility safety monitoring:

- Companion computer (Jetson NX): Enables 6K static photograph transmission and 4K video streaming
- EO Camera: High resolution (4K, 6K) Sony camera with a 3-axis gimbal
- 1-Channel LiDAR: In order to achieve precise altitude maintenance during flight, a single-channel Lidar sensor is used to measure the actual relative altitude from the drone to the ground surface. This allows for accurate monitoring of the drone's height above the terrain, rather than relying on GPS altitude, enabling precise altitude control during flight operations. The precise localization of objects requires not only the absolute coordinates provided by GPS but also the distance from the ground surface.

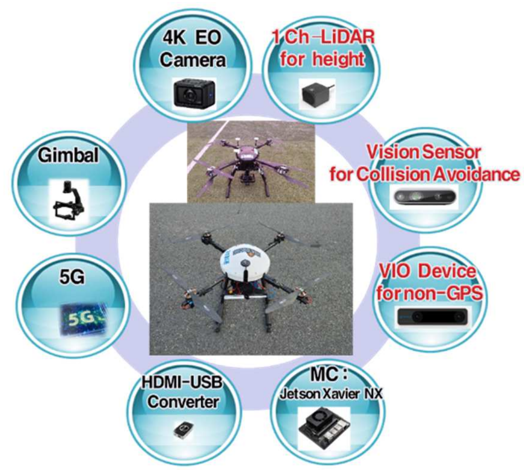

Fig. 3. The structure of the implemented dronefor dedicated for facilities inspection.

- Vision Sensor: A vision (depth) camera is installed for collision avoidance purposes.
- VIO (Visual-Inertial Odometry) device: A tracking camera used to measure the pose of the drone in non-GPS environments. It supports accurate posture and movement estimation.
- 5G network device and HDMI-USB converter
- Real-time live streming of high-resolution 6K static photographs and 4K videos using 5G technology

Figure 3 depicts the structure of the implemented drone utilized for inspecting various facilities.

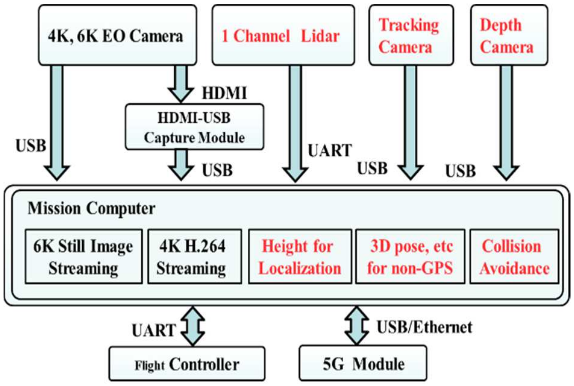

Fig. 4. The structural design of the drone for facility safety monitoring.

High-resolution 6K static photographs taken by the camera are directly transmitted to the companion computer (Jetson NX) via the USB port using Picture Transfer Protocol [1]. The companion computer then transmits the static photographs to the ground media streaming server using 5G networks based HTTP communication. The ground media streaming server multicasts high-resolution static photographs using an MJPG streamer [1].

Fig. 5. The developed drones for facility safety monitoring

Figure 5 shows the developed drones for facility safety monitoring.

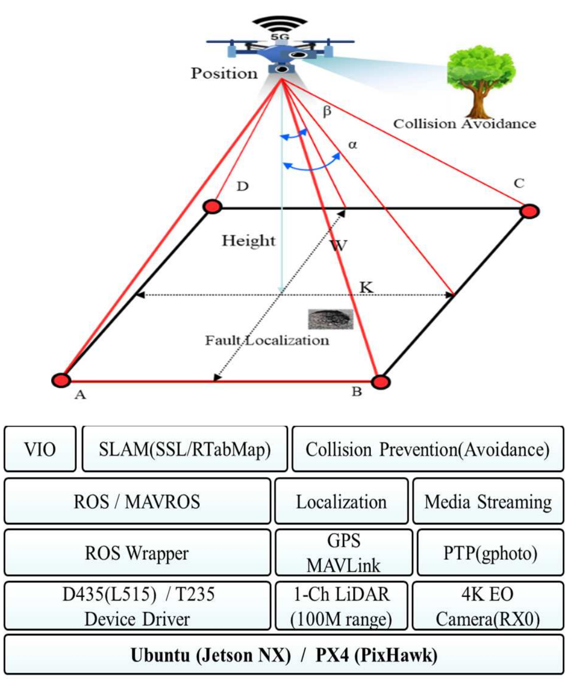

Fig. 6. The Localization of object for facility safety monitoring.

The companion computer then compresses the video into H.264 format and streams it to the ground Real-Time Streaming Protocol server (RTSP server) via 5G-based RTSP (Real-time video transmission Protocol). Serial communication between the flight controller (FC) and the companion computer is based on UART-USB converter.

V. Real-Time Media Streaming of 6K Still Images via 5G Network

The drone is sending high resolution 6K static photographs taken by the Sony Cam and transmitting them in real-time to the media server. These images are then multi-streamed through a web-based platform for flight monitoring, with a frequency of approximately every 5-10 seconds. Figure 7 illustrates the web-based multi-streaming of the drone's captured images.

Fig. 7. The images captured by the drone are being web-based multi-streaming.

VI. Conclusion

This research paper presents the implementation of a drone-based business model dedicated to facility safety monitoring. We also conducted a comprehensive evaluation of the system's efficacy by applying it to the inspection of defects in a real-world structure.. The configuration of the business model for facility safety monitoring encompasses the following components: 3-dimesion modeling of structures, development of specialized drones for facility safety monitoring, Live transmission of high-resolution 6K static photographs using 5G technology, capabilities, and real-time inspection based on the analysis of static photographs. To create a test environment, the developed drone was deployed within a sports arena, road, allowing the service framework to be applied in real time.

Acknowledgment

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