ENG EC 601 Project 1

Field of Interest: Imaging and Flight Control

Problem Statement

The project is intended to use aerial drones to do an image survey of the target building, learning its details, and probably building a 3D model of the building’s interior and exterior structures, or getting a list of concerned objects from image recognition. It is a popular topic so far, yet it is related to a variety of fields, such as image processing, flight controls, wireless communications, 3D mapping and modeling, and choice of different sensors. After a through discussion with my classmates in the same topic, combining my previous experience with RC car cameras, as well as my interest in aerial drone products, I decided to focus more on the drone itself, together with the consideration and choice of camera as well as other sensor systems.

There are different types, sizes, prices and functionality of drones, based on their difference in target goals and working environment. As there are limited information I found so far about Talon Inc, and they only mention that they will be using drones to do survey on buildings, not any details in whether it is done from outside or inside, nor what they are trying to find out about the building, I can only guess that they probably what to use the drone to find out the general condition of the building from outside, and let the drone fly into the building, with limited autonomous navigation abilities inside the building and get a brief view of the equipments and conditions inside the building. The most common aerial drones used so far is designed and manufactured by DJI, and I will use their latest flagship product Magic 3 Pro Cine as an example. There are also other types of aerial drones, which are more expensive in terms of price, and have more specific field of usage. These will be further discussed in “List of Papers”.

In terms of sensor systems, the most common sensors used on drones so far is cameras, and it is also the sensor I have most experience with. Different drones have different cameras in terms of sensor size, photo and video resolution, focal length/field of view, as well as low light ability. There are also other sensors systems used in drones, and LiDAR is the most common example, which provides more accurate distance measuring and 3D modeling, especially in a dark room or in the night when lights are not sufficient.

Combining the drones design and sensor system choices, we can expand the problem further to the automated navigation control of the drones, which allows it to fly in limited space safely. I found a research by University of Utah, and it provided their experiment on aerial drone navigation in streets and alleys. It is not the closet related, but it does provide important information and conclusion for reference.

Applications

The aerial drones automated building survey has a lot of user applications. The brief report from [wingers.com](http://wingers.com)(2023) has already provided a basic review in it. A drone flies much closer to the ground than the survey satellites, and it is also much cheaper and easier to recycle and redeploy. The drones can be used to building terrain maps, contour lines, or provide details for urban planning. The DJI drones have already been widely used in this purpose. When the environment is proven to be dangerous, such as chemical leak, or inaccessible, such as a very steep slope, the drones can fly above the ground very easily, and provide the information human hard to get.

Another important application of aerial drone survey, although not very related to building surveys, is worth mention in my opinion. In modern battlefield, drones can take off from any soldiers’ hand, have a full surveillance of the entire battlefield within miles, and provide the location of enemy targets as well as guidance to missiles. This application has been widely used on Ukraine, and it has received good results so far. Lockheed Martin has its aerial drones specifically built for this purpose, and it will be further discussed.

Suppose the navigation and flight control technology has become more advanced and more reliable, it is also possible to let the drones fly inside the building and have a more detailed survey of the building. I found a company called Fixar(2023) and they are developing a 4 axis drone able to fly in combined space such as building interior. If the product become available and reliable, it is possible to let the drone fly into the buildings about to collapse, scan the overall structure of the building, and provide a detailed safety report. It is also possible to set up a list of interesting objects, let the drone fly into a certain building, and retrieve the number of objects from the list, without a human inspector. A very specific and real life example can be using the drones to get a list of tables and chairs in each classroom of the instruction building before the semester starts. In this way, the seating capacity of each classroom will be clearly displayed to class managers, and each class can be assigned to a proper room for maximized resource management.

Initial List of Papers

There are quite a few research conducted in those related areas. I would like to list the four most useful papers I found so far, together with another existing products that is related to aerial drone mapping and modeling.

The first is the research by Mike Atwood, David Ord, Alex Vasquez and Jacob Zenger from University of Utah (2019). It focuses on navigation and flight controls of drones using feedbacks from different sensors to provide flight stability control, collision alert. The team used micro computers to serve as flight computers, and a reprogrammable flight controllers to control the drone. They used Wi-Fi for communication methods, USB-C cameras for 3D mapping and environmental sensing, and Bluetooth for location tracking. They managed to achieve autonomous flight and mapping with these basic hardwares, and it has proven that in a controlled environment flight control and mapping at the same time is possible.

The second research paper is by Hyungki Kim & Soonhung Han (2018) about 3D modeling from images and maps. It used machine learning techniques, with panoramic images to provide a wide view of the environment. It managed to achieve good results for shape and color detection of buildings.

The third research paper is by Zhan Quanxi, Zhang Junrui, Sun ChenYang, Shen Runjie, and He Bin from Tonga University (2022), and it specifically focused on navigation of multi rotor drones in a confined space.

The fourth research paper is by Guiye Lin, Andrea Giordano, Kun Sang, Luigi Stendardo, and Xiaochun Yang (2021) about using LiDAR like technology to map buildings in a small village in China.

The first product I would like to mention is the battlefield surveillance drone made by Lockheed Martin. The Indago 3 UAV they designed has a low acoustic signature, very long datalink range, and a wide range of optical zoom in and out.(n.d.). All these abilities make the drone extremely useful on a real battlefield as a surveillance drones.

The second product I would like to mention is Sony Airpeak S1 (n.d.). As Sony also makes cameras, the drone can carry a professional camera with it, allowing it to deliver high image quality for filmmakers and photographers. The endurance of the drone, as a result of higher payload, is much shorter.

The third product I would like to mention is DJI Magic 3 Pro (2023). It has balanced price and performance. It has multiple cameras for different field of views, allowing user to take photos and videos with different narrative options. It has moderate size, endurance, flight range, and price tag.

Open Source Projects

I found some open source projects on Github that utilized machine learning and deep learning to recognize furnitures and buildings. These could be further look into when building an image classifier.

<https://github.com/RexxarCHL/library-seat-detection/tree/master>

<https://github.com/OlafenwaMoses/ImageAI>

<https://github.com/GabZech/building-segmentation-tutorial>

Next step and future work

The most important next step, in my opinion, is try to get more information about the details of the project. As previously discussed, there are a lot of branches and varieties in how and what these aerial drones are used, and the user goal differences make the drone design and sensor system design different with each other. If the project is intended to conduct survey of the buildings only from outside, then relying on existing open sources projects, products and research papers, such as the research on aerial drone navigation by University of Utah (2019), and the mapping of small village using lasers by Guy Lin, Andrea Giordano, Kun Sang, Luigi Stendardo, and Xiaochun Yang (2021). If the project has higher goals to achieve, say let the drone fly into the building and scan furnitures inside the rooms, then it is going to be much more complicated. A lot of more research, specifically on AI/Machine Learning based image recognition and flight controls will need to be further explored.

ChatGPT Results

Question/Prompt: Please give a brief discussion on aerial drone survey on buildings.

Answer: Aerial drone surveys have become increasingly popular in the field of architecture, engineering, and construction (AEC) for assessing and surveying buildings. These surveys involve the use of drones, also known as unmanned aerial vehicles (UAVs), equipped with various sensors and cameras to capture high-resolution images and data from the air. Here's a brief discussion on how aerial drone surveys are used in building assessment:

1. \*\*Data Collection and Imaging\*\*:

- Aerial drones are equipped with high-resolution cameras that capture images of buildings from various angles and altitudes.

- These images can be stitched together to create detailed 2D and 3D maps of the building and its surroundings.

- Thermal cameras can be used to detect temperature variations, which can identify insulation issues and heat loss.

2. \*\*Structural Inspections\*\*:

- Drones can access hard-to-reach areas of buildings, such as rooftops and facades, without the need for scaffolding or manual inspections.

- High-definition imagery allows engineers to spot structural defects, cracks, or other signs of wear and tear.

3. \*\*Site Planning and Design\*\*:

- Aerial surveys can provide an accurate representation of the site, which is valuable for architects and designers in the planning phase of new construction or renovations.

- The 3D models generated from drone data can be used to assess the impact of a new building on its surroundings.

4. \*\*Progress Monitoring\*\*:

- Drones can be used to monitor construction progress over time by capturing images or videos at regular intervals.

- This helps project managers track work, identify potential delays, and ensure that construction is proceeding according to plan.

5. \*\*Safety and Efficiency\*\*:

- Drone surveys reduce the need for workers to access dangerous or difficult-to-reach areas, improving safety on construction sites.

- They also reduce the time and cost associated with traditional manual surveys.

6. \*\*Environmental Assessments\*\*:

- Aerial surveys can be used to assess the environmental impact of a building project, including factors like tree coverage, water bodies, and wildlife habitats.

7. \*\*Documentation and Reporting\*\*:

- The data collected by drones can be used to create detailed reports and documentation, which are valuable for regulatory compliance, insurance claims, and legal purposes.

8. \*\*Cost Savings\*\*:

- Aerial drone surveys are often more cost-effective than traditional survey methods, as they require fewer personnel and less equipment.

9. \*\*Regulatory Compliance\*\*:

- Regulations regarding drone use in building surveys vary by location, and compliance with these regulations is essential to avoid legal issues.

10. \*\*Data Processing\*\*:

- After data collection, advanced software can be used to process and analyze the data, generating actionable insights for decision-makers.

In summary, aerial drone surveys offer a versatile and efficient solution for building assessment, providing detailed data that can be used for planning, construction, maintenance, and compliance purposes. However, it's crucial to adhere to local regulations and safety guidelines when conducting drone surveys on buildings.

Analysis: ChatGPT does provide a good overall structure and introduction to look into the topic, but it is missing critical technical details, so a more detailed manual research is still required.

Reference

*Ars-S1 Airpeak S1 - Sony Pro*. ARS-S1 Airpeak S1 - Sony Pro. (n.d.). https://pro.sony/ue\_US/products/professional-drones/ars-s1#SATD151689BreakTheBoundariesOfAerialExpression-ars-s1

Atwood, M., Ord, D., Vasquez, A., & Zenger, J. (2019). *Project report: Autonomous Flight & Mapping - University of Utah*. Project Report: Autonomous Flight & Mapping. https://my.ece.utah.edu/~kstevens/4710/reports/drone-mapping.pdf

*DJI Mavic 3 pro - specs - DJI*. DJI Official. (n.d.). https://www.dji.com/mavic-3-pro/specs

*Drones for indoor mapping and Inspection - Fixar UAV*. FIXAR. (2023, September 11). https://fixar.pro/products/fixar-indoor/

*Indago 3 - UAV*. Lockheed Martin. (n.d.). https://www.lockheedmartin.com/en-us/products/indago-vtol-uav.html

Kim, H., Han, S. Interactive 3D building modeling method using panoramic image sequences and digital map. *Multimed Tools Appl* **77**, 27387–27404 (2018). <https://doi.org/10.1007/s11042-018-5926-4>

Lin, C.-H., Hobson, M., & Yin, R. (2018). *REXXARCHL/Library-seat-detection: A seat occupancy detection system that leverages existing surveillance camera infrastructure and uses CV techniques to map which seats are available in the library.* GitHub. https://github.com/RexxarCHL/library-seat-detection/tree/master

Lin, Guiye, Andrea Giordano, Kun Sang, Luigi Stendardo, and Xiaochun Yang. 2021. "Application of Territorial Laser Scanning in 3D Modeling of Traditional Village: A Case Study of Fenghuang Village in China" *ISPRS International Journal of Geo-Information* 10, no. 11: 770. <https://doi.org/10.3390/ijgi10110770>

Olafenwa, M. (n.d.). *Olafenwamoses/imageai: A python library built to empower developers to build applications and systems with self-contained computer vision capabilities*. GitHub. https://github.com/OlafenwaMoses/ImageAI

Perroud, D. (2023, June 20). *Surveying with a drone-explore the benefits and how to start*. Wingtra. https://wingtra.com/drone-mapping-applications/surveying-gis/

Silva Zech, G. da, Kath, J., Manohara, K., Winkler, F., & Zoueini, N. (n.d.). *Gabzech/Building-segmentation-tutorial: A tutorial providing an end-to-end workflow of image segmentation of buildings based on aerial images.* GitHub. https://github.com/GabZech/building-segmentation-tutorial

Zhan, Q., Zhang, J., Sun, C., Shen, R., & He, B. (2022, December 15). *Hybrid stability augmentation control of multi-rotor UAV in confined space based on adaptive backstepping control*. arXiv.org. https://arxiv.org/abs/2212.07656