Feasibility Assessment of sUAS-based FOD Detection System

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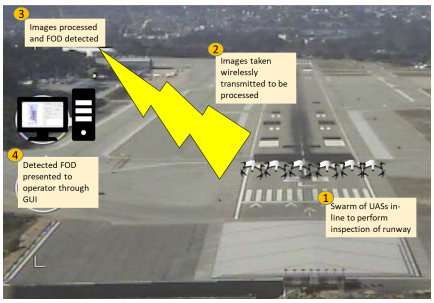
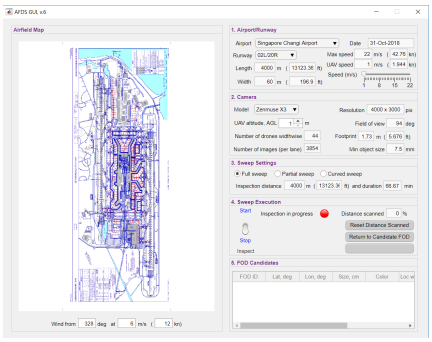
This thesis aimed to determine if a system of unmanned aerial systems could be used to perform and speed up the airfield inspection process and detect foreign object debris (FOD), the system configuration to enable object detection, and how it could be incorporated into airfield operations.

Automated FOD Detection System



The concept of the Automated FOD Detection System (AFDS) is a swarm of UASs based at the Airfield Management area. When the command is given to start the inspection, the sUAS swarm would travel to the start of the inspection area and then traverse the runway, taxiway or ramp and take images at regular intervals. The images would then be wirelessly transmitted to be processed for the presence of FOD. Detected FOD are then presented to the operator through the graphical user interface (GUI).

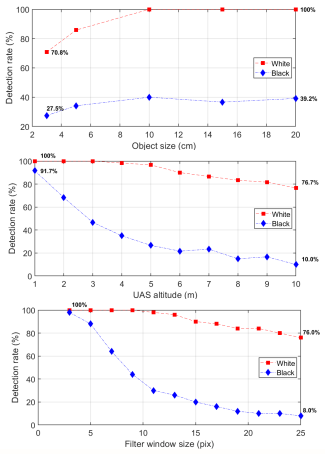


Computer Vision

The main research idea was in computer vision, where the object detection algorithm was as such:

1. Read background image file which forms the baseline.
2. Read current image file where FOD may be detected.
3. Convert and filter the images into grayscale.
4. Align the two images.
5. Find the difference of the current image from the background image.
6. Filter the results to sharpen the resultant binary image.
7. Draw bounding boxes around image objects which are suspected FODs.
8. Overlay the bounding boxes on the current image file.

Design of Experiment and Results



The system configuration of the AFDS being one of the research questions, four system parameters were studied. They were 1) object colour, 2) object size, 3) UAS altitude, and 4) filter size. The study found that 1) white objects were more easily detected compared to black objects; 2) detection increased as the size of the object increased, 3) detection decreased as the UAS altitude increased, and 4) detection decreased as the filter window size decreased.

Filter window size (pix) \ UAS altitude AGL (m)	1	2	3	4	5	6	7	8	9	10
3	100%	100%	100%	100%	100%	100%	100%	100%	100%	80%
5	100%	100%	100%	100%	100%	100%	100%	60%	80%	40%
7	100%	100%	100%	100%	80%	40%	80%	20%	20%	0%
9	100%	100%	100%	80%	40%	20%	0%	0%	0%	0%
11	100%	100%	80%	20%	0%	0%	0%	0%	0%	0%
13	100%	80%	60%	20%	0%	0%	0%	0%	0%	0%
15	100%	80%	20%	0%	0%	0%	0%	0%	0%	0%
17	80%	80%	0%	0%	0%	0%	0%	0%	0%	0%
19	80%	40%	0%	0%	0%	0%	0%	0%	0%	0%
21	80%	20%	0%	0%	0%	0%	0%	0%	0%	0%
23	80%	20%	0%	0%	0%	0%	0%	0%	0%	0%
25	80%	0%	0%	0%	0%	0%	0%	0%	0%	0%

For the most challenging case of detecting black objects, a detection rate table was created based on the UAS altitude and filter window size. This table helps in understanding and justifying the AFDS configuration.

Benefits and Future Work

The potential benefits of the research are tremendous, with the need to move towards automation in Singapore well-known with the aging and decreasing population. The use of sUAS to perform inspection of airfields are starting to take root overseas, as well as in power line and other infrastructure. The results of this research would support the design of such systems to be able to detect objects down to the required size. Future work would involve design of the control systems for the swarm of sUASs, as well as to test the reliability and suitability of the system in an operational environment.