PROJECT TITLE: USE OF DRONE IN ABC CONSTRUCTION

Quarterly Progress Report
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1. Background and Introduction

In recent years, drone technology has entered many industries and applications, greatly impacting and revolutionizing their processes. It is strongly believed that drone technology has also an important role to play in ABC construction, especially when geometry control, inspection, and surveying/mapping are concerned.

The recent researches [1-4] on effectiveness and applications of drones have demonstrated the great potential for drones in inspection of hard to reach bridges, but at the same time pointed to technological limitation of existing drone designs preventing their full implementation. A comprehensive and up-to-date knowledge of drone technology is very essential in addressing these limitations. The current commercially available rotorcraft drones are designed for general-purpose application but successful implementation of such systems in ABC requires certain technical considerations.

The ABC Drone (ABCD) project will provide guidelines to overcome the many challenges of using drones for inspection and construction programs. Aircraft's stability at the inspection site due to gust, wind driven rain, unsteady turbulent flow or induced airflow (from the blades) when flying close to the bridge, aircraft overall efficiency for longer endurance, balancing and fast setup, track control sensor communication, inspection instrumentation setup, software and hardware integration of the data acquisition systems with wireless communication capabilities, tolerability to impact of inappropriate landing are among issues that need to be addressed in application of drones.

2. Problem Statement

One of the main challenges in ABC construction is geometry control at fabrication and construction stages, especially during installation and erection of prefabricated large elements. Also, as it is concerned with the rehabilitation projects, inspection for detection of damages, and survey and mapping of the affected areas necessary for design and construction has required costly operation and traffic interruption that is in contrast with ABC objectives.

This study therefore will include identification of tasks and processes in ABC that can benefit from drone application, and development of preliminary drone systems that would best serve these processes. The study will also provide parameters and hardware/software requirements; identify the existing drone systems that readily are applicable and those that would require adaptation or new designs. An implementation demonstration for conceptual verification will be performed for selective identified process(es) and application(s) and compared with current practices.

3. Research Approach and Methods

The overall approach of this project will be organized in three basic stages; search of background information for identification of processes within ABC construction where drone application would be beneficial, and development of appropriate drone systems through determination of important parameters for applicable drones and necessary hardware and software, and finally verification of the concepts through experimental trials within the scope and budget limitation.

4. Description of Research Project Tasks

The following is a description of tasks carried out to date.

Task 1 – Identification of ABC processes benefiting from drone application

A review of available literature and data is performed to study various processes and operations carried out for an ABC bridge construction, for both new construction and rehabilitation of existing construction. These processes are categorized based on how they would benefit from drone application.

Task 2 – Review of drone technology and its application in the construction industry

Available drone technologies are reviewed within construction and other industries, and general applications benefiting the construction industry. Currently, we are at the stage to proceed with the purchase of the drone to be able to start experiments.

Task3 – Determination of drone design and parameters

With the knowledge gained from the first two tasks, the overall design of the drone can take place based on the requirements determined from task one, and the sensors and technologies discovered in task 2.

Task4 – Hardware and software integration

After the final design of the drone has been determined, the appropriate software will be identified to interpret the data gathered by the sensors placed on the drone.

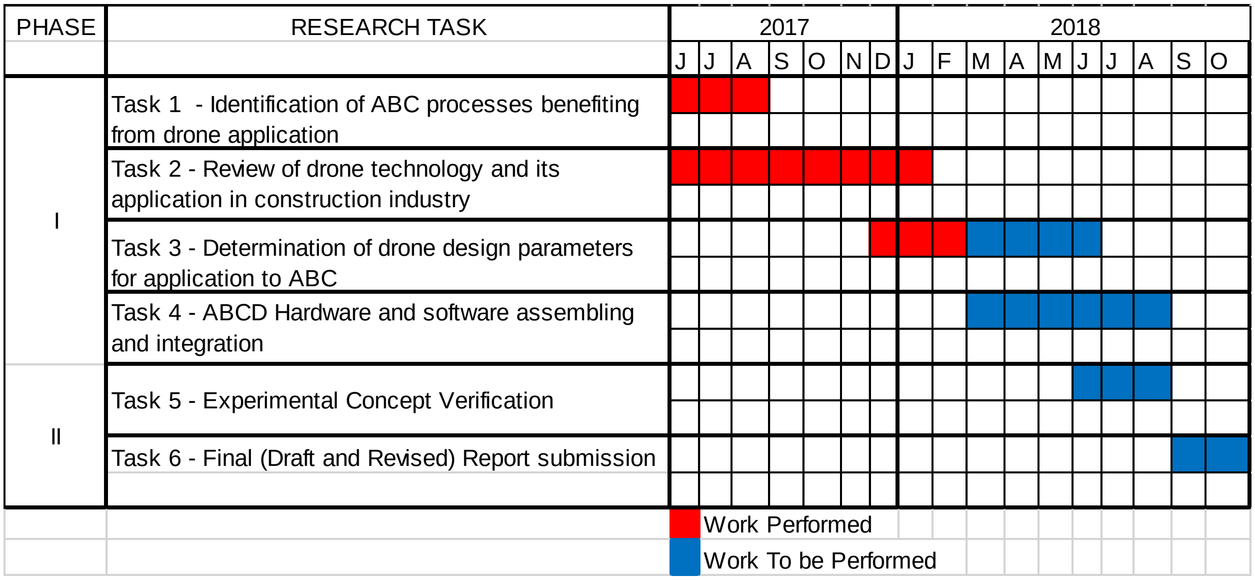
5. Expected Results and Specific Deliverables

For the next project period we expect to determine the drone design parameters for application to ABC and assemble and integrate ABCD hardware and software.

6. Schedule

Progress of tasks in this project is shown in the table below.

Table 1: Timeline



7. Identification of ABC processes benefiting from drone application

In addition to new constructions, ABC has a valuable presence and application for rehabilitation projects where time and traffic interruptions are definitely more important than new construction. Rehabilitation projects are heavily dependent on inspection and damage detection prior to construction, as well as surveying and mapping during and after construction.

Design of retrofits and strengthening normally requires an accurate knowledge of geometry and condition, including scanning and measurement, of the affected areas normally out of reach and hard to access, a task that can be performed effectively and efficiently using a drone. In customary approach, these activities require time and traffic interruptions, and inflict heavy costs and safety concerns

8. Review of drone technology and its application in the construction industry

Reference [5] researched how the use of drones have been prevalent in surveillance. On construction sites, drones are used to watch workers to ensure the safety of the workers as well as the ensuring the workers are making sure the building is being built according to construction standards.

A comprehensive study done by Reference [6] founded that drone inspections of bridges would decrease the time, money, and interruption needed to inspect a bridge. This is important because it is estimated there are 300,000 bridges in the United States alone that need inspection. A challenge that MnDOT came across during their bridge inspection research was that according the laws pertaining to bridge inspection there must be a certified inspector on site to review data that the drone has acquired. This significantly slows down the process compared to if all the data were sent to a central office to be reviewed simultaneously rather than at one time. In the second part of the research done by MDOT they analyzed in more detail how drones can assist in remote sensing transportation infrastructure. An example where they used the UAV to replace an existing method was to do thermal imaging of roads. Normally the camera would be attached to the vehicle and would try to cover as much of the road as possible. Using the UAV, they were able to cover a wider view of the road but were sometimes limited by the amount of equipment they could use based on the size of the drone. Another drawback was the limited flying time. They concluded the advantages and advantages had to be weighed based on the scenario.

Reference [7] did research on using drones to repair bridges. They determined that while drone inspection does significantly decrease the amount of time, money, and traffic interruption, it is not worth the cost of training, certification (can cost up to $5000) and getting past regulations. Fig. [1] shows a current method used to inspect bridges that is costly and not efficient.

Figure 1: Example of technique currently used to inspect bridges

Once government involvement reduces, it is much more worth the effort. They also claim that civilians are working hand in hand with the government to make this more of a reality. Another problem that they ran into is when bridge inspection takes place over an overpass, the potential of the UAV malfunctioning would put drivers driving under the overpass at significant risk. Furthermore, pilots do not have the same visualization that they normally would if they were physically inspecting the bridge. Although the pilot has real-time camera feed from the UAV, it is not the same as being right there. Another problem they realized was GPS signal would be lost in parts underneath the bridge, they suggested a way that this problem could be solved using the use of SLAM which is a statistical estimation technique where a UAV can build a map of an unknown area, while simultaneously deducing its location within this map.

Reference [8] did research on UAV use on building inspection. This research took place in Europe where there is not as much limitations in terms of where they can fly the UAV. They found that while they were limited by the amount of weight they were legally allowed to put on the UAV, they were able to put the necessary scanners and cameras on the UAV, so they could get accurate pictures and data from the building. The biggest problem they had was the data and photos were not always clear and they would try and stabilize the flight platform. They would also improve anti-collision and navigation systems as well as route planning algorithms to expand the automation of the process.

Research by reference [9] in Australia looked at how UAVs could be used to inspect light posts rather than putting people in danger by having them go up tall unstable ladders. They tested 32 poles and had a succeeded of the time in tracking the pole and hovering in a position relative to it. A current limitation of the system is due to the poor yaw estimates produced by the onboard IMU. Yaw control is based on this estimate so a drift in yaw estimation causes a yaw rotation of the vehicle, which in turn yields a y-axis controller error. The vehicle therefore keeps rotating about the pole even without operator input. Improving the yaw angle estimates by means of a magnetometer or a visual compass is an area of future work. Another limitation of the system is its susceptibility to the effects of direct sunlight and shadows found in outdoor environments. Edges are weak under strong sunlight due to the small intensity difference between the pole edges and the background. Shadows on the other hand can create an intensity gradient on the surface of the pole and this may be falsely detected and tracked as the pole edge. To avoid these challenges our experiments were conducted in the absence of direct sunlight and we will improve the robustness to these effects in the future.

Reference [10] found that using a drone for bridge inspection would only require 3 people which is fewer than the number currently required. It also costs less to use a drone rather than using large special equipment or setting up scaffolding. Using this technique increases efficiency, feasibility, safety, and affordability. A problem they had when inspecting the bridge using GPS navigation was the drones became very difficult to fly without a steady GPS signal. To counteract this problem, the researchers implemented laser and image navigation.

Reference [11] researched the use of an Unmanned Aerial Vehicle (UAV) to see if the use of UAVs made the process of inspecting bridges cheaper and less labor intensive while also not interrupting the flow of traffic. The UAV used were multicopters chosen because of the lightweight body allowing for additional sensors to be added and for proficiency in maneuvering. These multicopters can move autonomously using GPS signal or inputted way points. A problem encountered by using the GPS signal is that because it is a high frequency signal it does not have good penetrative power, thus the multicopter did not always have a consistent or accurate signal. To counteract this problem, they would use a navigation mode that would automatically have the UAV fly to the next waypoint. When carrying out tests in an open area, using GPS signal the drone flew very well maintaining a low degree of wobble even in strong wind. However, when using the navigation mode, the results were inconsistent. Sometimes the UAV would perform flawlessly, other times the wind would affect flight path and there would be a crash. Once testing on the bridge began a problem that was discovered was that problems found were not always to scale depending on the distance of the camera to the problem. This is countered by resizing the image using an image pyramid. The resized images would then be put into programs to analyze the health of the bridge.

9. Drone Analysis

SenseFly Albris

The SenseFly Albris (Fig. [2]) seems like the best option to use in our use case. It features a robust and simple to use flight control software that allows it to navigate confined spaces, as the blades are protected by bumpers, and the drone features obstacle avoidance sensors, all the while remaining easy to use. It also features a very flexible camera system allowing for a wide range of vision below and above the drone. It includes both a high quality digital camera as well as a thermal camera. The only issue that the SenseFly Albris has is its high price tag of about twenty thousand dollars.

Figure 2: SenseFly Albris

As stated previously, the SenseFly Albris seemed like the best option to use in our case. Therefore, we contacted the Florida distributor for SenseFly products, Geo Networking, who gave us the price of a ready to fly kit. It also includes powerful post processing software called Pix4D, which allows the user to create 3D images using the images captured with the Albris. Cost of such system is being explored for possible purchase and implementation.

Flyability Elios

The Flyability Elios is a drone that has similar capabilities as the Sensefly Albris, but is better suited for enclosed spaces. The reason it is better suited for enclosed spaces is because it has a gimballed cage around the airframe, protecting itself and objects around it from collisions.

10. FAA Regulations That Must be Complied With

The Federal Aviation Administration has put into place many regulations on Unmanned Aerial Vehicles that must be complied with in order to move forward with the final goal of this work which is to inspect the thousands of bridges in the United States and around the world which require inspection. The regulations that have been run into before are outlined in Ref. [6]. The major regulations included that cause the most problems for drones are the regulations surrounding the various distances that a drone must be away from while flying, the required battery life or flight time that must be remaining, and that a certified pilot be the one flying the drone at all times. All regulations put in place by the FAA must be complied with unless granted an exemption in paper by the FAA. These regulations and all regulations required by the FAA can be found in Ref. [12].

Figure 3: Flyability Elios

Flight Distances

The FAA has three main distances that drones must be adhere to when flying. First, the drone must fly at least 500 feet away from any person not involved in the inspection. Second, the drone cannot fly more than 400 ft in the air. Third, and perhaps the most challenging regulation, is that drones cannot fly within 5 miles of an airport due to the risk of a fly away drone putting large aircraft in danger. Another requirement the FAA has in place is that the drone must be in the Visual Line of Sight (VLOS) of the pilot of all times regardless of how far away from the drone he or she is.

Flight Time

In addition to the distance requirements put in place by the FAA, they have also put in measures regarding the flight time and battery of the drone as to ensure maximum safety. The FAA requires that the flight of UAV must be suspended once the remaining flight time is less than 20 minutes or there is less than 20% battery remaining, depending on the drone. For example, the drones that have a flight time of only around 20 minutes must end their flight with 20% remaining which makes that flight time even more limited. However, with the more expensive drones that have flight times up to 50 minutes they must end their flight with 20 minutes of flight time remaining, lowering their flight time to only 30 minutes.

Requirement of Pilot

The FAA also requires that a certified pilot be the one flying the drone. This is becoming a problem due to the fact that many certified pilots do not have bridge inspection experience, and certified bridge inspectors rarely have certification to fly a drone. This forces the group overseeing the inspection to have to pay additional for additional training and certification in order to inspect the bridge.

11. Proposed Solutions to FAA Regulations

We believe that we will be able to set a precedent in providing safety measures on these drones that we will be able to convince the FAA to change their regulations to make drone inspection of bridges more accessible to all city inspection crews. Currently if a bridge inspection wants to occur, the investigating crew must apply for an exemption from the FAA which, in the case of Ref. [6] took months to get approved, at which point their research was already completed.

Fishing for Drones Net

We propose that in order to convince the FAA to end their regulation prohibiting flight with 500 feet of those not involved, we create a create a device designed to catch a falling drone from crashing onto streets where there are drivers or pedestrians. This device would consist of four movable legs with a fishnet type net attached to the top of the four corners of the legs, as shown in Fig. [4]. The net measure twelve feet wide, covering 1 lane of traffic, and be ten feet long.

Figure 4: Basic Design of Proposed Net (created in SolidWorks)

Tether Preventing Fly-Aways

In order to have the FAA remove the restriction prohibiting drone flight within five miles from an airport, we propose attaching a tether Fig. [5] to the drone so that in the event of a fly-away the drone can be kept under control. We believe that the use of a tether can also be used to solve the problem of the short battery life by making the tether holding the drone an extended charging cable that will charge the drone as it inspects.

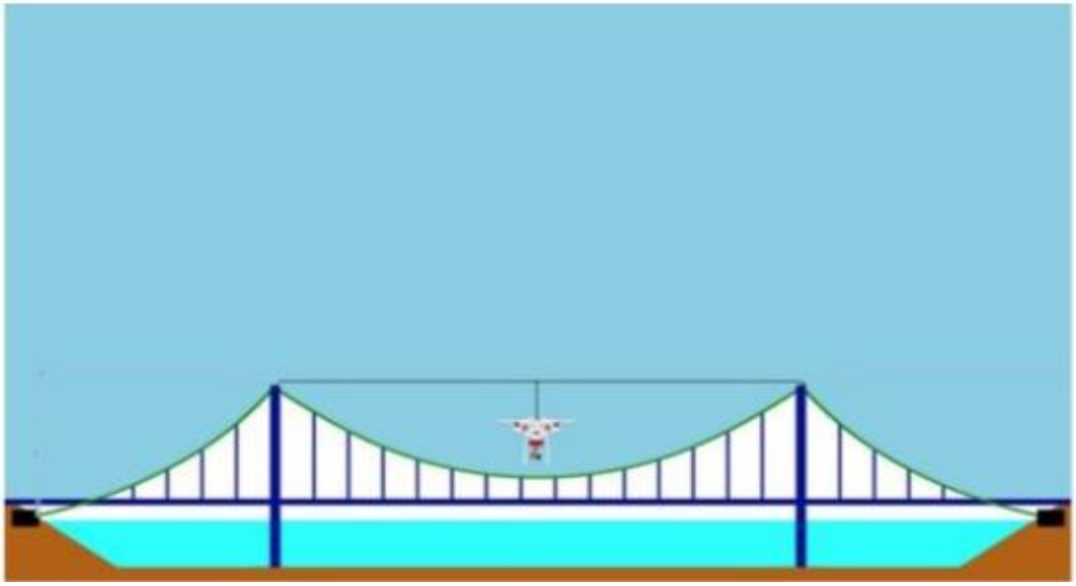


Figure 5: Basic rendering of what tether would look like

12. Conclusion

There are multitude of ways that drones can be used to make the lives of humans around the world more efficient. We have outlined here how drones have various aspects of engineering and they contribute to the main goal of improving, in terms of cost, efficiency, and safety, of inspecting bridges. Furthermore, we have shown that the technology to inspect bridges is readily available and only requires further testing to optimize the use of UAVs. The optimization of these drones could open up the opportunity to further utilize this technology in future endeavors and continue to revolutionize the limitless potential of these unmanned vehicles. We believe that currently the use of UAVs is too inhibited by regulations not allowing for bridge inspection using the UAVs achieve the goal of being quicker, cheaper, and less interactive with society, even though it does still achieve the goal of being safer. We believe that with further research and testing the FAA will loosen their requirements if there is a safety protocol developed that can guarantee safety for all those not involved, which is what we are trying to develop in order to make drone bridge inspection more feasible in the near future.

13. References

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