30 May 2018

MEMORANDUM FOR: AFIT/ENG
ATTENTION: MAJ BINDEWALD

FROM: 1ST LT WILLIAM E. DALLMANN (GCE-19M)

SUBJECT: Thesis Prospectus: Real-Time Pose Estimation for Automated Aerial Refueling

1. The United States Air Force currently does not have the ability to refuel Unmanned Aerial Vehicles (UAVs) in flight. The current method of aerial refueling for piloted aircraft is not viable for a UAV due to the communication latency between a UAV and its ground-based operator. The ability to refuel UAVs in flight is necessary to increase a UAV's flight duration and maximum weapon payload. Therefore, an automated aerial refueling (AAR) solution is needed to eliminate the communication latency problem. The proposed research will develop a system that uses stereo vision and software to output real-time position and orientation (pose) estimates of a refueling aircraft.

2. Various aspects of AAR have been previously researched by others. Researchers at the Air Force Institute of Technology (AFIT) have conducted stereo vision experiments within a 3D virtual world to make pose estimates. However, these experiments were fully contained within the virtual world and did not include pose estimates in the real world. In 2015, Duan and Zhang implemented a real-time pose estimate system by pointing stereo vision cameras at monitors with simulated aircraft. This approach also did not use real world aircraft for the pose estimate. Other AFIT researchers have previously used a Vicon chamber as a truth system to make pose estimates of real world objects but the pose estimates were not evaluated in real-time. My research will extend previous research by making real-time pose estimates of real world aircraft.

3. The research will be performed by conducting real world experiments using stereo vision cameras to capture imagery of ground vehicles. Ground vehicles will be used in place of aircraft due to the large cost of flight tests. A computer processor will then be used to execute pose estimate algorithms previously developed at AFIT. The processor will execute the algorithms in real-time and output a pose estimate. Determining the accuracy of the position estimates will require the use of a differential global positioning system (DGPS) to serve as the truth system for the distance between the stereo vision cameras and the real-world object. Additionally, the error output from the pose estimation algorithms will be used to measure the accuracy of the orientation estimate of the real-world object. Progress will be measured by achieving centimeter level accuracy with the DGPS system and being able to output pose estimates of real world objects in real time using the stereo vision cameras and the computer processor. Finally, the research will be deemed successful if the real-time pose estimates can be made with centimeter level accuracy prior to a March 2019 flight test.

4. Both the position estimates and the orientation estimates of the real-world object will be documented. A comparison between the pose estimates and the DGPS to determine the correctness of the estimates will also be completed. This research will delve deeply into software engineering for the real-time processing of the pose estimates and the interfacing between the processor and the stereo vision cameras. Therefore, a detailed analysis of the software required to output real-time results will also be included in the thesis.

5. The sponsor for this research desires to make the refueling of UAVs in flight a reality. If the results of this research show that centimeter level pose estimates can be achieved in real time, then this technology could be further tested using real tankers and UAVs to achieve the sponsor's AAR goal. Furthermore, the ability to refuel UAVs in flight would extend their mission capabilities by increasing their endurance and weapon selection for world-wide Air Force operations.

6. Proposed thesis committee:

a. Dr. Scott Nykl, Chair / Thesis advisor _____ *(signature)*

b. Dr. Douglas Hodson, Committee member _____ *(signature)*

c. Dr. Robert Leishman, Committee member _____ *(signature)*

7. Sponsor: Air Force Research Lab (AFRL)

a. Name: Dan Schreiter

b. Title: Aerospace Engineer

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8. Software engineering and camera visualization techniques encompass the fundamental research areas for this research. Therefore, my course plan includes the following courses to prepare me to successfully complete this research:

- CSCE 593 Intro to Software Engineering
- CSCE 693 Software Evolution
- CSCE 684 Information Visualization

WILLIAM E. DALLMANN, 1st Lt, USAF
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1st Ind, AFIT/ENG

MEMORANDUM FOR AFIT/ENG

I acknowledge receipt of the above thesis prospectus and thesis committee. This prospectus will be maintained in the department files for students graduating between Sept 2018 and Jun 2019. The thesis should be prepared in accordance with the AFIT Thesis Guide. Good luck!

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