Thesis Proposal

Title: Simulating Wing-Sensors on a Sailplane Airfoil To Evaluate Usefulness For Pilot Feedback

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Proposal:

(1) Provide a brief but complete description of the research problem to be solved. In a separate paragraph, specify the goals of this research.

We are working towards a system for sensing the local airflow outside a glider and sending feedback regarding that airflow to the pilot. For example, we may use an array of MEMS (Micro Electro-Mechanical Systems) air pressure sensors on the glider wing, and feed the information from these sensors back to the pilot on their skin through tactile rendering technology. Providing this kind of feedback to the pilot may be practically useful (e.g., to help the pilot locate lift), may enhance safety (e.g., to detect stall conditions), and may also enhance the quality of the flying experience.

This thesis research marks the start of a research programme to outfit the wing of a glider with sensors and feed that information back to the pilot. Some of the general problems which we will be addressing in this research programme are:

1) Will the feedback information provide interesting and useful discriminations to the pilot?

2) Will the feedback information have adverse impact by adding to the pilot's workload? In general, it seems important for such a system to not add to pilot's workload.

3) Conversely, can the feedback information reduce the pilot's workload? For example, if we feedback airspeed information in a tactile sense this could reduce pilot's reliance on the in-cockpit airspeed indicator.

4) How are we going to give feedback to the pilot so that he actually senses the local airflow conditions outside the glider?

The specific goal of this research is to start to address the first general problem above. We will do this using a wind tunnel simulator because at this initial stage of the research programme, we do not have sensors or a wing surface useful for this project. The wind tunnel simulator will be used to both simulate a wing and sensors on a wing. Software will be written to visualize the results of this simulation and provide an initial evaluation of the question of whether the sensory information may provide interesting and useful discriminations to the pilot.

(2) Provide a descriptive, one to two paragraph literature review, which sets the framework for research and cites recent references which establish the importance of the work or problem to be solved. (Three to five references from recent, reviewed

publications are sufficient.)

Wind tunnel simulators (e.g., FoilSim; Benson, 1997) are used to simulate the airflow outside of an aircraft. These simulators are based in the equations of fluid dynamics (Shaughnessy, Katz, & Schaffer, 2005). More generally, such simulations comprise computational fluid dynamics (CFD; e.g., Moin & Bewley, 1994; Moin & Kim, 1997). CFD based wind tunnel simulators are often used for aircraft development to simulate new aircraft designs. For example, they are used in the early design stages, when engineers are establishing key dimensions of the aircraft. Examples of current computational fluid dynamic software packages include SolidWorks with Cosmos Flo Works (http://www.solidworks.com/pages/products/cosmos/cosmosfloworks.html), and Fluent (http://www.fluent.com/). These packages can be used to construct models of 3D physical structures (e.g., a wing airfoil) and simulate fluid flow over these structures. They can also be used to simulate sensors on those simulated structures.

The sensors that we will eventually use on the glider wing may sense various properties of the local airflow such as pressure, airspeed and turbulence. Researchers have constructed artificial sensors based on the study of insect haircell physiology. For example, Ozaki, Ohyama, Yasuda, & Shimoyama, 2000, have constructed artificial insect haircell sensors using micro-mechanical structures (consisting of micro-cantilevers and micro-strain gauges) of size 3000 μm in length, 250 μm in width, 8 μm in thickness, composed into arrays. These sensors were able to accurately measure airflow velocity in range of tens of cm/s to 200 cm/s. While these artificial haircell sensors are interesting it may prove more practical however for us to rely on commercially available technology. One such sensor is the SMD500 Altimeter/Barometer module from Bosch. This is a high precision digital pressure sensor with range of 300 to 1100 hPa.

Methods of providing feedback to the pilot include haptic, visual and auditory. Haptic is related to the sense of touch and haptic rendering is a process of creating forces on the user's skin to produce tactile sensation. Typically these forces are generated under computer control. Haptic rendering on a person's torso (Jones, Nakamura, & Lockyerb, 2004) can be used to provide navigational cues to the operator. Jones et al., (2004) used a matrix of electromechanical stimulators mounted in a vest that are sequentially activated to provide information required for navigation. Tactile displays (Bach-Y-Rita, Collins, Saunders, White, & Scadden, 1969) have also been used as visual substitution for blind people. Vision substitution aims at providing some equivalent of vision via hearing or touch. In this display system, four hundred solenoid stimulators were arranged in a 20x20 array built into a dental chair. The stimulators, spaced 12 mm apart, had 1 mm diameter Teflon tips which vibrated against the skin of the back. A television camera mounted on a tripod, scanned the visual scene and presented stimuli onto the skin of the back of the blind subjects. With training, the blind subjects were able to use the system in various visual tasks.

In this research programme, we want to give tactile feedback to the pilot to provide information about airflow conditions such as lift or stall. We focus on tactile feedback because visual and auditory stimuli already exist in the pilot's environment.

This feedback system may enhance the quality and safety of the flight.

(3) List the resources (in terms of software, hardware and people) required to complete the work. If not available within the department, indicate how/where such resources will be obtained. If only one instance of a required resource is available indicate how you will account for failure of that resource.

Software:

- SolidWorks
- Cosmos FloWorks

  Both are licensed and available on ITSS computers.

Hardware:

- Any current desktop/laptop computer.

People:

- Dr. Daniel Pope, Department of Mechanical and Industrial Engineering. He is an expert in Computational Fluid Dynamics.

(4) In a numbered list below, specify each step required to solve the problem along with a specific target date for the completion of that step. (The last two steps should be the write-up of the thesis and the completion of the oral exam and colloquium, respectively, along with their scheduled dates.)

	Completion Dates (Estimated Time Required)	**Goals**
1	Dec 31, 2007 (1 month)	Draft of thesis introduction (Chapter 1)
2	Jan 31, 2008 (1 month)	Construction of 3D wing model using SolidWorks
3	May 31, 2008 (3 ½ months)	♦ Using the SolidWorks model, conduct FloWorks simulation of fluid flow and sensors
	(½ month)	SolidWorks and FloWorks simulation written up as draft of Chapter 2
4	June 30, 2008 (½ month)	♦ Design of abstract interface for software
	(½ month)	♦ Draft of Chapter 3
5	July 15, 2008 (½ month)	Designing of layout of GUI
6	July 31, 2008 (½ month)	Start of implementation of driver for FloWorks output
6	August 31, 2008	Summer break
7	November 31, 2008 (3 months)	♦ Continue implementation of driver for FloWorks output

		♦ Programming of GUI that gives visualization of data
8	December 31, 2008 (½ month)	Data collection design, evaluation design
	(½ month)	Data collection design, evaluation design written up as draft of Chapter 4: Evaluation
9	February 14, 2009 (1½ months)	Chapter 1, 2 & 3 revisions
10	March 15, 2009 (1 month)	Evaluation/Application of GUI to simulation
11	April 30, 2009 (1½ month)	Chapter 4 revisions, writing Discussion & Conclusion
12	May 15, 2009	Defending thesis

(5) Specify clearly how the results of the research will be evaluated. What objective measures will be used to establish that the goals of the research have been met?

The purpose of this evaluation is to determine if the feedback information can provide interesting and useful discriminations to the pilot. The simulation of the wing sensors will be done by measuring simulated air pressure at specific points on the simulated wing. For example, for a particular angle of attack (the angle between the wing and the direction of the air flowing over the wing) we will measure the pressure at fixed points on the wing. The GUI will visually show the pressure values simulated at these various points. The simulations will be repeated by varying the angle of attack, including both stalled and non-stalled wing conditions. We will show a set of GUI displays for different simulations to the adult subjects and ask if they can detect any visual difference between the different simulations. We are using these visual discriminations as a simulation of haptic discrimination (our intended final goal). We assume that if visual discrimination is possible, then haptic discrimination will be possible. We can thus use the subjects' visual discriminations to evaluate if the sensors might provide useful discrimination to a pilot. We will also use a similar process and vary the convective lift conditions to see if our subjects can discriminate visually between these GUI representations.

(6) State clearly the contribution to research that this work will make.

We are focused on simulating a wing and an array of sensors under various conditions. The purpose of these simulations is to access whether this kind of system will be able to provide useful discriminations to the pilot. This work, may give us a direction towards improving the safety and quality of flight for a glider pilot.

Signatures: ____
Student

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Advisor

References

Bach-Y-Rita, P., Collins, C. C., Saunders, F. A., White, B., & Scadden, L. (1969). Vision substitution by tactile image projection. *Nature, 221*, 963-964.

Benson, T. J. (1997). Interactive educational tool for classical airfoil theory. *AIAA Aerospace Sciences Meeting,* Reno, NV.

Jones, L. A., Nakamura, M., & Lockyerb, B. (2004). Development of a tactile vest. *12th International Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems,* 82- 89.

Moin, P., & Bewley, T. (1994, June). Feedback control of turbulence. *Applied Mechanics Reviews, Vol. 47, No. 6*(Part 2) S3-S13.

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Ozaki, Y., Ohyama, T., Yasuda, T., & Shimoyama, I. (2000). An air flow sensor modeled on wind receptor hairs of insects. *The Thirteenth Annual International Conference on MEMS 2000,* (23-27) 531 - 536.

Shaughnessy, E. J., Katz, I. M., & Schaffer, J. P. (2005). *Introduction to fluid mechanics*. New York: Oxford University Press.