The 2010 IEEE/RSJ International Conference on
Intelligent Robots and Systems
October 18-22, 2010, Taipei, Taiwan

Mixed Reality for Unmanned Aerial Vehicle Operations in Near Earth Environments

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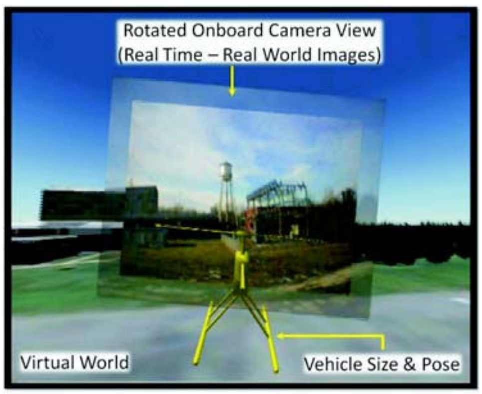

Fig. 1. Screenshot of the graphical interface for the UAV pilot demonstrating the chase viewpoint during UAV operation in a near-Earth environment.

I. INTRODUCTION

Future applications will bring unmanned aerial vehicles (UAVs) to near Earth environments such as urban areas, causing a change in the way UAVs are currently operated. Of concern is that UAV accidents still occur at a much higher rate than the accident rate for commercial airliners. A number of these accidents can be attributed to a UAV pilot's low situation awareness (SA) due to the limitations of UAV operating interfaces. The main limitation is the physical separation between the vehicle and the pilot. This eliminates any motion and exteroceptive sensory feedback to the pilot. These limitation on top of a small field of view from the onboard camera results in low SA, making near Earth operations difficult and dangerous. Autonomy has been proposed as a solution for near Earth tasks but state of the art artificial intelligence still requires very structured and well defined goals to allow safe autonomous operations. Therefore, there is a need to better train pilots to operate UAVs in near Earth environments and to augment their performance for increased safety and minimization of accidents.

In this work, simulation software, motion platform technology, and UAV sensor suites were integrated to produce mixed-reality systems that address current limitations of

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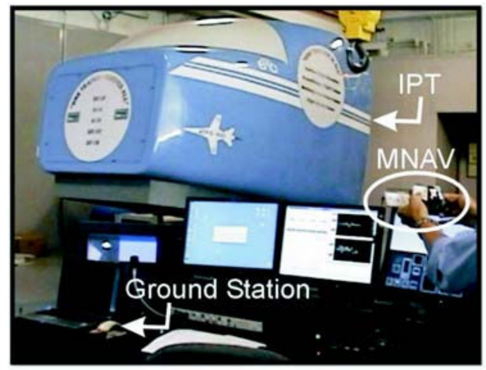

Fig. 2. IPT 4-DOF motion platform from ETC being wirelessly controlled with the IMU.

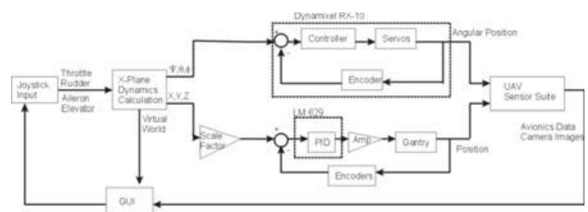

Fig. 3. Block diagram of the experiment setup.

UAV piloting interfaces. The mixed reality definition is extended in this work to encompass not only the visual aspects but to also include a motion aspect. A training and evaluation system for UAV operations in near Earth environments was developed. Modifications were made to flight simulator software to recreate current UAV operating modalities (internal and external). The training and evaluation system has been combined with Drexel's Sensor Integrated Systems Test Rig (SISTR) to allow simulated missions while incorporating real world environmental effects and actual UAV sensor hardware. A block diagram of this setup can be seen in Figure 3.

To address the lack of motion feedback to a UAV pilot, a system was developed that integrates a motion simulator into UAV operations (Figure 2). The system is designed such that during flight, the angular rate of a UAV is captured by an onboard inertial measurement unit (IMU) and is relayed to a pilot controlling the vehicle from inside the motion simulator.

Efforts to further increase pilot SA led to the development of a mixed reality chase view piloting interface as seen

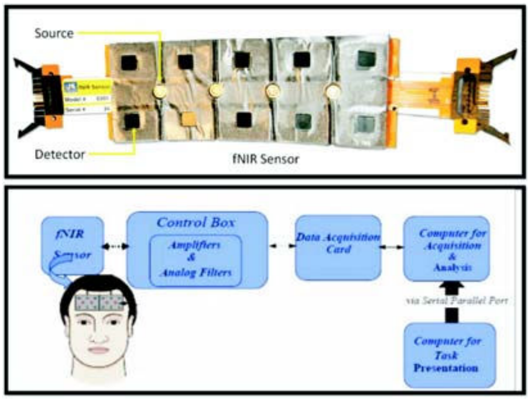

Fig. 4. Top: fNIR sensor showing the flexible sensor housing containing 4 LED sources and 10 photodetectors. Bottom: fNIR Block diagram reprinted from [1]

in Figure 1. Chase view is similar to a view of being towed behind the aircraft. It combines real world onboard camera images with a virtual representation of the vehicle and the surrounding operating environment. A series of UAV piloting experiments were performed using the training and evaluation systems described earlier. Subjects' behavioral performance while using the onboard camera view and the mixed reality chase view interface during missions was analyzed. Subjects' cognitive workload during missions was also assessed using subjective measures such as NASA task load index and non-subjective brain activity measurements using a functional Infrared Spectroscopy (fNIR) system.

The fNIR sensor consists of four low power infrared emitters and ten photodetectors, dividing the forehead into 16 voxels. The emitters and detectors are set into a highly flexible rectangular foam pad, held across the forehead by hypoallergenic two-sided tape. Wires attached to each side carry the information from the sensor to the data collection computer. The components of the fNIR systems are seen in Figure 4. The use of functional near-infrared (fNIR) brain imaging in these studies enabled an objective assessment of the cognitive workload of each subject that could be compared more easily than the subjective test results. The Drexel Optical Brain Imaging Lab's fNIR sensor uses specific wavelengths of light, introduced at the scalp. This sensor enables the noninvasive measurement of changes in the relative ratios of de-oxygenated hemoglobin (deoxy-Hb) and oxygenated hemoglobin (oxy-Hb) in the capillary beds during brain activity. Supporting research has shown that these ratios are related to the amount of brain activity occurring while a subject is conducting various tasks [1]. By measuring the intensity of brain activity in the prefrontal cortex, one can obtain a measure of the cognitive workload experienced by the subject [2], [3], [4]. Another added benefit is the design of the sensor itself which allows for ease in portability and enables the monitoring of subjects in actual or realistic environments. This is compared with other brain imagining modalities such as fMRI that require large specially designed rooms and minimal movement by the subject during tests [5].

Behavioral analysis showed that the chase view interface improved pilot performance in near Earth flights and increased their situational awareness. This was shown by a more efficient flight path (ie. tighter turns around corners) and more accurate positioning over targets. fNIR analysis showed that Chase view subjects' average oxygenation levels was significantly lower than Onboard subjects. This signifies that Onboard view subjects were using more mental resources to conduct the flights. This result is most likely attributable to the narrower viewable angle and rolling of the environment in the onboard view, which require more cognitive processing by the subject to construct an accurate working mental model of the environment and the aircraft's position in it.

Real world flight tests were conducted in a near Earth environment with buildings and obstacles to evaluate the chase view interface with real world data. The interface performed very well with real world, real time data in close range scenarios.

The mixed reality approaches presented follow studies on human performance and cognitive loading. The resulting designs serve as test beds for studying UAV pilot performance, creating training programs, and developing tools to augment UAV operations and minimize UAV accidents during operations in near Earth environments. More details of this work can be found in [6], [7], [8].

REFERENCES

[1] K. Izzetoglu, "Neural correlates of cognitive workload and anesthetic depth: fnir spectroscopy investigation in humans," Ph.D. dissertation, 2008.

[2] J. Milton, S. Small, and A. Solodkin, "On the road to automatic: Dynamic aspects in the development of expertise," *Clinical Neurophysiology*, vol. 21, pp. 134–143, 2004.

[3] A. Kelly and H. Garavan, "Human functional neuroimaging of brain changes associated with practice," *Cerebral Cortex*, vol. 15, pp. 1089–1102, 2005.

[4] R. Poldrack, "Imaging brain plasticity: conceptual and methodological issues - a theoretical review," *Neuroimage*, vol. 12, pp. 1–13, 2000.

[5] M. Izzetoglu, K. Bunce, H. Ayaz, A. Devaraj, and B. Onaral, "Functional near-infrared neuroimaging," *IEEE Trans Neural Syst Rehabil Eng*, vol. 12, no. 2, pp. 153–159, 2005.

[6] J. Hing, K. Sevcik, and P. Y. Oh, "Improving unmanned aerial vehicle pilot training and operation for flying in cluttered environments," in *IEEE International Conference on Intelligent Robots and Systems*, St. Louis, MO, 2009, pp. 5641–5646.

[7] J. T. Hing and P. Y. Oh, "Development of an unmanned aerial vehicle piloting system with integrated motion cueing for training and pilot evaluation," *Journal of Intelligent and Robotic Systems*, vol. 54, pp. 3–19, 2009.

[8] J. Menda, J. Hing, H. Ayaz, P. Shewokis, B. Izzetoglu, K.and Onaral, and P. Y. Oh, "Optical brain imaging to enhance uav operator training, evaluation, and interface development," *SUBMITTED TO Journal of Intelligent and Robotic Systems*, 2010.