

Development of a Test-Bed for Synthetical Ergonomics Evaluation of Pilot

Wei Liu^{1,2}, Xiu-gan Yuan², Zhong-qi Liu², Rui Ma², and Wei-yong Kang²

¹ School of automation, Beijing university of Post Technology, Beijing, 100876, China

² School of aviation science and engineering, Beijing University of Aeronautics and Astronautics, Beijing, 100083, China
twhlw@163.com

Abstract. The study of pilot perception has evolved from examining simple tasks executed in reduced laboratory conditions to the examination of complex, real-world behaviors. A test-bed for evaluating models of pilot behavior in which a set of infrared video-based eyetrackers to monitor subjects' eye movements while they perform a range of complex tasks such as driving, and manual tasks requiring careful eye-hand coordination was developed. The real cockpit platform is provided to subjects as they pilot in a virtual scene; a dual-haptic interface consisting of two touch-screen display devices and a shift allows free control within the cockpit.

Keywords: test-bed, eye tracking, haptic interface, ergonomics.

1 Introduction

The study of human behavior is challenging for many reasons. Historically, experimenters have attempted to make such studies tractable by reducing the complexity of both the environment and the task under study. As a result, much of what is known about human behavior is restricted to over-simplified tasks, such as single eye movements made in response to the onset of a signal light, or a reach to an isolated target in a dark field^{[1][2]}. We have been striving to expand the range of behaviors to include the kind of complex behavior that makes up flight tasks. In that effort, we are developing a test-bed in which the behavior of pilots can be studied as they perform arbitrarily complex tasks.

A concern about such experiments is the ability to make meaningful conclusions about pilot performance because of the very complexity we are striving to understand. The use of virtual scenes/panels allows us to maintain enough control over the visual and haptic environment to permit meaningful analysis. In addition to traditional metrics of performance (such as reaction time, success rates, etc.), we monitor subjects' eye movements to provide an externally observable marker of attention. Electrocardiograph recordings can also be used to provide multiple indicators of physiological state. In order to accomplish the goal, many component subsystems must be successfully integrated. It is necessary to generate complex, stereo virtual scene/panels. The generated images must be displayed with sufficient fidelity to

provide a strong sense of immersion so that natural behaviors can be observed. The visual and haptic simulations comprise the perceptual input to the subject; a critical aspect of the test-bed goal is the ability to monitor subjects' cognitive state as they perform complex tasks in the virtual flight. Each of these elements is discussed in the following sections. See figure 1.

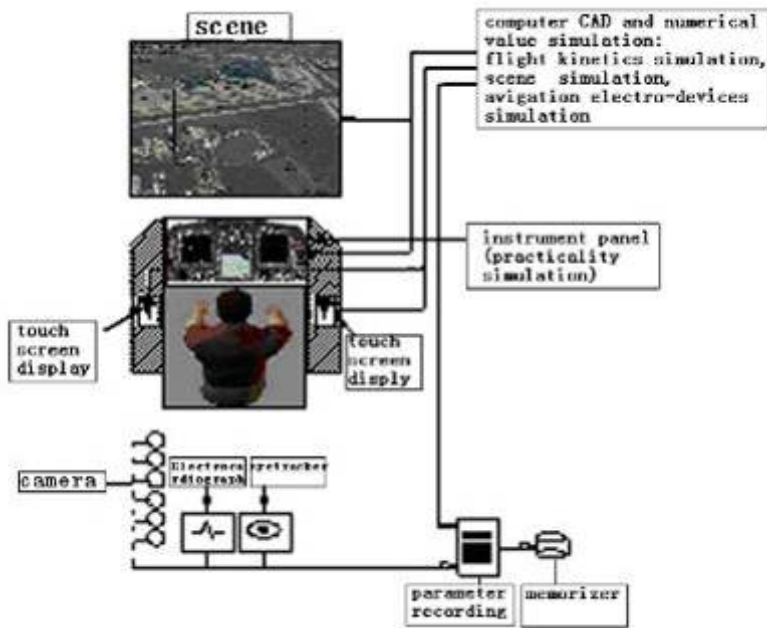


Fig. 1. A test-bed system principle figure of synthetical ergonomics evaluation of pilot

2 Graphics Generation and Display

The heart of the graphics generation system is a double-processor PC equipped with two Pentium 500 processors and two special software Mutigen-Vega. The system generates stereo image pairs at up to 60 Hz, depending on the complexity of the scene. Figure 2 shows a stereo scene.

In addition to generating the graphics, the PC is responsible for interfacing with other computers and equipment in the test-bed. The PC is equipped with a high-speed serial interface board capable of simultaneous communication with haptic interface, eyetrackers, and Electrocardiograph systems. A special-purpose 12-bit analog-to-digital board reads steering, accelerator, and brake signals from the flying simulator.

Central to pilot-based virtual scene systems is the ability to keep the position and orientation of the pilot, in order for the graphics engine to render the appropriate scene given the current viewpoint.

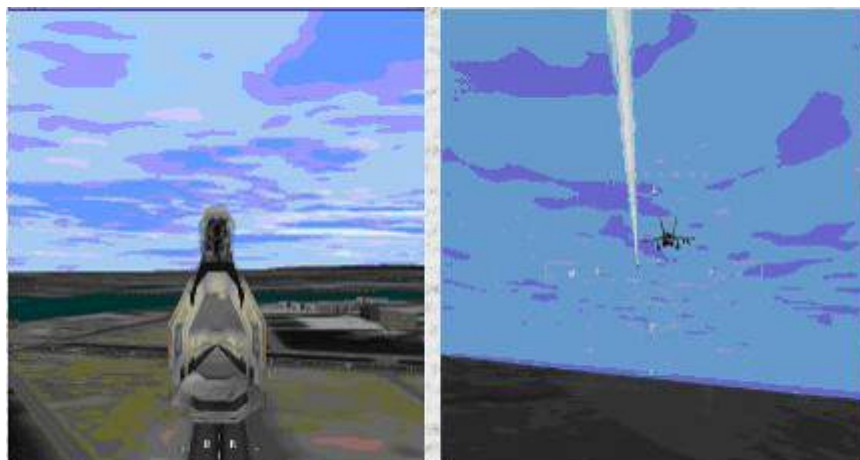


Fig. 2. Flying environment stereo scene

3 Driving Simulator and Motion Platform

3.1 Driving Simulator

One of the components of the virtual scene we use to study complex behavior is a flying simulator. The simulator is based on a frame in which the steering column has been instrumented with a low-noise rotary potentiometer and the accelerator and brake pedals are instrumented with linear potentiometers. A constant voltage supply across each potentiometer produces a variable voltage from each control that is read by a multi-channel sample-and-hold 12-bit A/D board on the bus.

Subject flight in sky, an extensible environment designed by Vega, Figure 2, shows a sample from the environment. We have added fighter planes and scenes to the environment that move along pre-defined or interactively controlled paths. These objects, as well as other planes can be placed in the environment through a configuration file that makes it easy to customize the environment. The visual environment is also easily modified to simulate lighting at any time of day or night, and the addition of fog.

3.2 Motion Platform

To aid our goal of making experiences in the virtual scene as close as possible to those in the real world, the flying simulator is mounted on a real plane cockpit platform. See figure 3. The platform, along with the scene, generates for the subjects the feeling of linear accelerations for heave, surge and sway, and angular accelerations for pitch, roll, and yaw. The platform virtual controller and shift are controlled by a host PC that is connected to the scene via serial interface. The host PC accepts acceleration values and calculates optimum linear and angular values for the visual scene subjects will view.



Fig. 3. Flying on a real plane cockpit platform

4 Experiment System of Instrument/Controller Layout (ESICL)

Due to different layout designs inducing different results of manipulation, layout and/or color of instrument, controller on the panel should be changed by the effect of ergonomics at any moment at the stage of designing. Experiment System of Instrument/controller Layout (ESICL) is a set of simulation systems that adopt computer technology. ESICL can make “Electronical instrument /controller devices system”(or soft instrument/controller panel), and thus the designer can control directly various outlines of panel, shapes of instrument, and layouts of controller on the screen by interactive technology. At the same time, the results of simulation experiment will be achieved by ESICL after designing.

5 Indicators of Cognitive State: Eyatracking

Central to the lab goal of studying complex behavior is the ability to monitor subjects’ use of attention and other aspects of their cognitive state. Monitoring eye movements is a powerful tool in understanding behaviors^[3]. In previous work with real tasks, we have shown that eye movements are a reliable metric of subjects use of attention and as a gauge of cognitive state^[4]. Recorded eye movements provide an externally observable marker of attentional state and of strategies employed in solving complex, multi-step problems. Particularly important is the fact that eye movements can sometimes reveal low-level strategies that are not available to the subject’s conscious perception. Complex tasks are often serialized into simpler sub-tasks that are then executed serially^[5]. In some cases rapid task-swapping is observed between multiple subtasks^[6]. While this is evident in the eye movement record, subjects’ self-reports in such tasks reveal that they are unaware of the strategy^[7].

Tracking subjects’ eye movements in virtual scene/panels presents a special challenge. EMMS system employs infrared video-based eyetrackers that determine

the point-of-gaze by extracting the center of the subject's pupil and the first-surface reflections from video fields. Tracking both pupil and first-surface reflections allows the image-processing algorithms to distinguish between eye-in-head movements and motion of the eyetracker with respect to the head. An infrared-emitting diode (IRED) is used to illuminate the eye.



Fig. 4. Subject flying with EMMS

The EMMS system calculates an eye position signal on each video field (i.e. 50 Hz). Single measurements can be read out at that rate or averaged over multiple fields to reduce signal noise. The system also digitizes the rendered image from the PC and overlays a cursor indicating the subject point-of-gaze on that field. In addition to the video record showing gaze on the virtual scene, the eye position signal from the EMMS system is sent via serial port to the PC. Accuracy of the eye position signal is approximately 1 degree in the central 20 degrees of vision and 2 degrees in the periphery.

The EMMS system is capable of tracking eye movements at rates greater than 50 Hz with special eye cameras whose vertical scanning can be controlled externally. By limiting the vertical scan to half the normal image height, two scans can be made in the time usually used for a single scan. The controllers analyze both images in each field, providing a 100Hz sample rate. The increased temporal frequency comes at the cost of vertical field. The higher temporal sampling rate is important for contingent display, while the eyetracker signal is used to initiate changes in the virtual scene/panels based on eye position or eye movements. See figure 4.

The DLL is called from within the Recognition and Biofeedback program. The Recognition and Biofeedback program chooses which data (in a continuous recording) need to be sent for further processing via the Matlab program. This program may send return information to the PC through a serial port interface; saves recognition data; calculates whether correct recognition has actually occurred (using available trigger codes); and may read previously processed data from a Matlab file

for a demonstration of recognition speed. We use the Matlab program because it enables the rapid prototyping of algorithms for use in the system and because it allows the easy swapping of algorithms for recognition/feedback/analysis. All routines are Matlab M-files to enable easy use of different recognition routines.

6 Summary

The test-bed provides a valuable tool in understanding complex pilot behaviors because it offers a unique combination of flexibility and control. Virtual scene/panels generation and displays coupled with visual and haptic interfaces create a rich family of virtual environments for psychophysical experiments. The use of integrated eyetrackers and concurrent Electrocardiograph recording gives us a window into subjects' use of attention and their cognitive state as they complete complex, multi-step tasks.

Acknowledgments

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