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# Measures for Simulator Evaluation of a Helicopter Obstacle Avoidance System

Joe De Maio
Army Aeroflightdynamics Directorate
Crew Station Research and Development Branch

Thomas J. Sharkey
David Kennedy
Monterey Technologies Inc.

Micheal Hughes
Perry Meade
CAE Electronics

NASA/Ames Research Center
Moffett Field, CA 94035

## Introduction

The U. S. Army Aeroflightdynamics Directorate (AFDD) has developed a high-fidelity, full-mission simulation facility for the demonstration and evaluation of advanced helicopter mission equipment. The Crew Station Research and Development Facility (CSRDF) provides the capability to conduct one- or two-crew full-mission simulations in a state-of-the-art helicopter simulator. The CSRDF provides a realistic, full field-of-regard visual environment with simulation of state-of-the-art weapons, sensors and flight control systems.

We are using the CSRDF to evaluate the ability of an obstacle avoidance system (OASYS) to support low altitude flight in cluttered terrain using night vision goggles (NVG). The OASYS uses a laser radar to locate obstacles to safe flight in the aircraft's flight path. A major concern is the detection of wires, which can be difficult to see with NVG, but other obstacles - such as trees, poles or the ground - are also a concern.

The OASYS symbology is presented to the pilot on a head-up display mounted on the NVG (NVG-HUD). The NVG-HUD presents head-stabilized symbology to the pilot while allowing him to view the image intensified, out-the-window scene through the HUD. Since interference with viewing through the display is a major concern, OASYS symbology must be designed to present usable obstacle clearance information with a minimum of clutter.

## OASYS Display Evaluation

The evaluation of OASYS has been conducted in stages. The first stage was a laboratory test of the readability of a variety of display formats. This evaluation was conducted using static symbology. In the second stage, pilots provided subjective ratings of a number of display qualities after having flown a limited fidelity real-time simulation. The third stage, now underway, consists of a high-fidelity simulator evaluation of selected OASYS displays in the CSRDF.

Preliminary Evaluations - The first two OASYS display evaluations provided preliminary screening to eliminate display formats that were too diffucult to read or were subjectively unacceptable to the study pilots. In the display readability experiment (1), straightforward measures of response time and accuracy were used. We used the results of this experiment to determine the set of candiate displays for evaluation in the limited fidelity simulation.

In the second experiment (2), involving simulated flight, we felt that the simulation fidelity was too low to permit use of objective data. Instead the pilots provided subjective seven-point ratings of the displays. The rating factors are shown in Table 1. The pilots also rank ordered the displays.

1. How interpretable was this symbology?
2. Rate the information content in this symbology.
3. Rate the clutter of this symbology.
4. Were you able to determine whether or not your turn rate exceeded the sensor's field of view?
5. Rate the amount of response time available with this symbology during turns.
6. Rate the amount of response time available with this symbology during straight flight.
7. To what extent were you able to determine the range of objects using this symbology?
8. To what extent were you able to distinguish between wires and blobs using this symbology?
9. How confident are you that this symbology will allow you to fly your aircraft without striking objects?
10. Overall, how would you rate this symbology?

Table 1. OASYS Display Rating Questions.

Only two of the rating questions showed significant inter-rater reliability. These were question 3 and question 8. Despite their consistency on question 8, the pilots did not feel that object type information (wires v non-wire blobs) was particularly important. They did feel that clutter was an important factor in display quality. Four of the highly rated display formats were selected for the full-scale simulator evaluation. A declutter option was also included for one display, based on the indicated undesirability of display clutter.

Full-scale Simulation - The purpose of the full-scale OASYS simulation test is to determine the ability of the system to support flight operation. This determination has several parts - does the OASYS reduce the incidence of wire and obstacle strikes, does the OASYS allow more precise or more aggressive flying, does the pilot's interaction with the display cause undesirable side effects. Issues here include increased workload, alteration of visual scanning and changes in flying technique.

We are measuring the effectiveness of the OASYS in preventing obstacle strikes simply by determining the rate of collisions with various types of obstacles. Obstacles other than wires fall into two categories, ground and objects projecting above the ground (e.g., poles, trees). Factors of interest regarding wire strikes are wire size and obliquity to the flight path.

Changes in visual scanning and pilot workload can occur because of display clutter, a problem identified in our preliminary studies. Problems of selective attention to symbology or outside scene imagery can also occur, and these may be exacerbated by registration mismatches caused by pilot head movement. We are addressing these issues both through subjective ratings and through analysis of pilot head movements, which are measured routinely for visual scene generation. Comparison of head movements with and without OASYS symbology will indicate whether presence of the OASYS display alters the way in which pilots scan the out-the-window scene.

An additional item of information that comes from the head position data is where the pilot looks for obstacles when not aided by OASYS. This information may be important for pointing the sensor during maneuvering, when the relevant information may not lay along the flight path vector. Such a situation is shown in Figure 1.

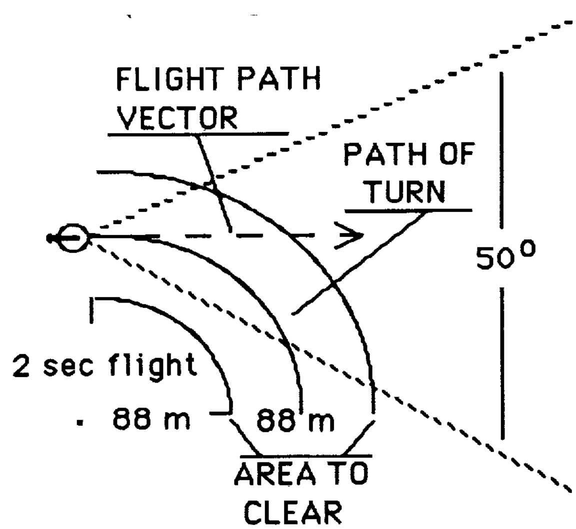


Figure 1. Location of Obstacle Information off Flight Path Vector. Desired clear path is 88 m wide, and desired look-ahead is 2 sec. OASYS field of regard is 50 deg.

The issue of changes in flying technique is challenging from the perspective of data collection and analysis. The simulation scenario involves free flight through a densely populated data base. Any object or terrain feature in the data base could potentially be an obstacle to flight. Thus the often used technique of triggering data collection or analysis based on mission time or location in the data base is not suitable. Instead it is necessary to identify maneuver initiation based on changes in the aircraft flight path and to determine the obstacle being avoided from the maneuver dynamics. Once the maneuver and obstacle have been identified, evaluation factors can be assessed for each obstacle avoidance maneuver individually.

The approach we are taking to maneuver identification is based on a procedure developed by De Maio et al (3). This procedure involves looking for threshold changes in the flight path to signal initiation of maneuvers. The salient points in a maneuver are shown in Figure 2. The threshold determination process works on rate of turn. Rate of turn is computed not in the horizontal plane, but instead it computes the turn rate in whatever plane the turn is executed. Thus a pull-up is a turn executed largely in the vertical, a level turn is execute largely in the horizontal and a climbing turn is intermediate between the two.

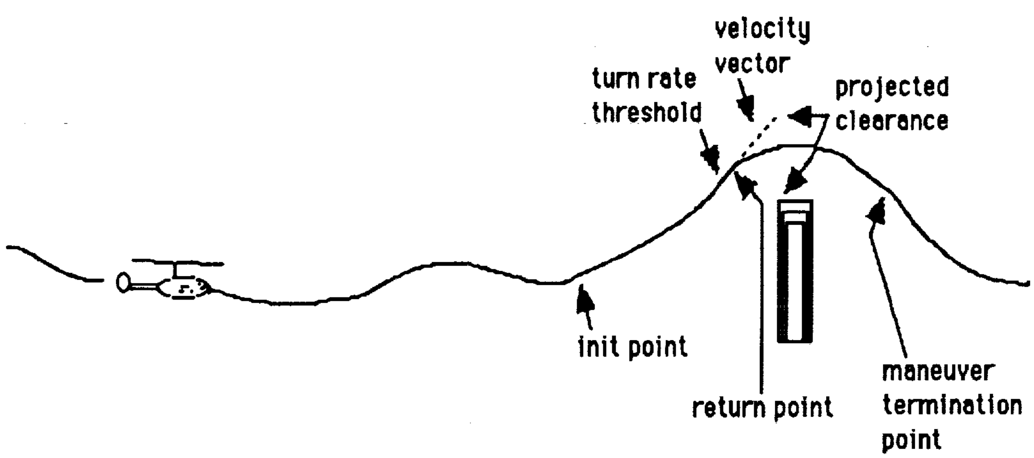


Figure 2. Obstacle Avoidance Maneuver Profile.

Once a suprathreshold turn rate is detected, the analysis works backward to identify the point at which the maneuver was intiated. This is the point where the direction of flight changes (e.g., down to up, left to right). From the initiation point we proceed down the original flight path to determine whether there was an object along it that would have constituted an obstacle to flight. If so a descriptive analysis of the avoidance maneuver is performed.

Conclusion

The CSRDF is being used for a comprehensive evaluation of the usability of OASYS to provide a pilot symbolic information necessary for obstacle avoidance. This evaluation included a preliminary evaluation of display readability using psychophysical methodology and measures. Based on this prescreening a set of candidate displays was developed for evaluation in a limited fidelity simulation. In this evaluation subjective pilot ratings were used to identify a set of four display for evaluation in full-scale simulation. The full-scale simulation provides realistic tasking under realistic conditions. In this simulation we are using conventional objective and subjective measures to evaluate OASYS performance. In addition we are developing innovative measurement procedures to respond to the specific requirements of the OASYS evaluation.

References

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