Visibility in the Aviation Environment

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Problems with visibility play an enormous role in a large number of fatalities in aviation accidents each year. These problems often occur in the context of proceeding visually into instrument meteorological conditions (IMC) and result in a variety of accidents both on the ground and in the air. The accidents not only occur due to visually demanding conditions but also because pilots sometimes fail to recognize conditions that make it difficult to detect other objects and/or may fail to take corrective action. The purpose of the present project is to develop research and educational materials that will help reduce accidents caused by problems of visibility in the aviation environment in the air and on the ground. Research includes analysis and quantification of the statistics of the aviation environment in the context of visibility and target detection. Further research is aimed at determining pilot performance as a function of these environmental statistics. The project will also advance the development of educational materials based on the results from the detection experiments.

Introduction

General

The present report represents the first annual report for this project due to a late funding date of April 2003 and covers activity from April of 2003 until October of 2004. There are several important goals that have been accomplished during this period which will be described below.

Purpose

Each year there are a large number of accidents in general aviation that result in controlled flight into terrain (CFIT) or collision with other aircraft or land based obstructions such as radio towers (Khatwa& Roelen,1996; O'Hare & Owen, 2002; Volpe, 1994). These accidents occur not only when there is continued visual flight into instrument meteorological conditions (IMC), but often times in conditions of clear weather (reviewed by Kraus, 1995; O'Hare & Owen, 2002). The problem of not being able to visually acquire other aircraft and terrain has its roots in several important issues.

1) *Learning to see the target*- Visual detection is an active task rather than a passive one. Efficient search and detection requires that the observer know what to look for, that is approximately where, when, and how it will appear. Just as with the auditory system, the process of sensory encoding requires prior knowledge for optimal performance. Student pilots are often unable to understand what air traffic controllers are saying on frequency until they learn what to expect to hear. Similarly pilots must learn what to expect to see in order to acquire visual targets optimally. Additionally, the more salient the target is the easier it is to detect.

For example when an air traffic controller calls “traffic, Cessna, 2:00, 2 miles, southbound, 6000” for a pilot, the pilot must know first where to look. The ability to judge azimuth is usually assumed as most pilots would be familiar with “clock” directions and particularly since the information is given essentially with an angular measure that does not change with distance to the target. However elevation is not as well learned because few pilots have an intuitive feel for how high or low traffic should be given the relative altitudes of the two aircraft and the distance. In this case the pilot must determine how much of an angle to look up or down at from relative altitude and distance information. Indeed most pilots even find it difficult to determine whether or not objects such as clouds or mountains are at the same altitude as the aircraft.

Pilots must also learn what to expect to see so the pilot must be able to predict the approximate shape and size of the target aircraft. The shape can only be inferred from relative direction of travel. This has to be computed from what is known about the relative directions of the aircraft. The size must also be computed from the relative distance of the aircraft and what is known about the size of that target. In the above example “Cessna, 2 miles southbound” is the information given, so that a pilot must calculate what the target airplane should look like from this information and what is known about Cessnas and the pilot’s own direction of travel. This is a complex task that requires experience to perform well.

The parameters described above are all easily calculated from known relationships. Training is required however for pilots to perform quickly and automatically.

We will describe below the initial design of some products that should aid the pilot in learning to see other aircraft in the flight environment.

2)Learning to judge the visual environment- There are three components to this issue a) the background, b) intervening atmosphere and c) lighting especially “flat-light”.

The background against which targets must be detected varies from low contrast, uniform (e.g. clear blue sky) to complex and high contrast (e.g. cityscapes and mottled mountainous terrain). In general, detection is inversely related to scene complexity. In other words, the more complex and higher contrast the background, the harder it is to detect a target on it.

In order to train pilots to judge conditions under which detection may be difficult we must first have a way to characterize the background. We must then model detection on different backgrounds composed of images from the aviation environment. We have investigated a leading model used for detection and have begun to apply the model to various images and test the model psychophysically employing detection experiments.

The results from these detection experiments should provide verification of the model of detection and evaluation of any real aviation background. This knowledge will allow us to educate pilots on recognition of dangerous conditions for detection.

In addition to research on the effects of backgrounds on detection, we have begun to investigate evolutionary adaptation to the aviation environment. Although it has been argued that most natural images show frequency spectra that fall off in amplitude as 1/f, there is ample evidence that the spectra of many scenes differ from 1/f significantly (e.g. Field & Brady, 1997). In the present study we have applied sparse coding algorithms to images from the aviation environment (Simoncelli & Olshausen, 2001). This algorithm produces basis functions which are believed to be generated in a similar manner to the receptive fields of visual cortical neurons, that is, by learning from the environment. Such an application provides insight as to the limits of applying our land based visual system to the demands of the aerial environment. We report these results below.

The second and third parts of learning to judge the visual environment (intervening atmosphere and lighting) are concerned largely with weather phenomenon. Whenever there is visible moisture, smoke, or other particulate matter in the air, visibility will be reduced. The visual effects of intervening atmosphere are well modeled by reduction in contrast and a diffusion of the light source. However, these factors can vary independently and have independent effects on the visual system.

While reduction of contrast will reduce the ability to detect outside objects increasingly with distance, light scatter may not. Light scatter may occur well above and below the path of the aircraft such that visibilities are essentially unrestricted yet depth perception and to some degree target detection will suffer greatly. Such conditions occur when flying over snow fields or water and dessert areas with a well diffusing overcast. Because the light is efficiently diffused in all directions, shadows are completely lost and judgment of distance and many target features are greatly disturbed. Pilots have been known to misjudge distance to targets and the ground, the slope of surfaces, and fail to detect large ground features (e.g. mounds of snow or sand) often with disastrous results.

To address the issue of flat light we plan to develop experimental procedures to quantify the degree of diffusion in an environment and to measure behavioral performance in simulated flat light conditions. The results from these experiments will form the basis for educational materials described below.

3) taking proper action

The educational materials for the present project will be focused on training pilots to recognize demanding visual conditions. Future experiments will address issues surrounding failure of pilots to take action once difficult visual conditions are encountered and recognized (see e.g. O'Hare and Owen, 2002).

Accomplishments and Results

Simulator

We have now completed the construction of simulator system with 180 deg of "outside" visual display (see fig. 1 below). This system still needs to be programmed to conduct detection and weather recognition experiments.

Fig. 1 Simulator for detection experiments.

Aviation Images

We have collected high quality digital images from the aviation environment over a large portion of the mainland U.S. and around the greater Anchorage area in Alaska. Many of these images have already been analyzed using sparse coding algorithms.

We have found that the basis functions "learned" by the sparse coding algorithm are different than those learned from land-based environment images. Applications of land-learned basis functions to the aviation images suggest that cortical visual development based on the terrestrial environment may not be optimal for the aviation environment. The results from this study have recently been presented at the annual Fall Vision Meeting of the Optical Society of America, in Rochester (Mizokomi and Crognale; 2004; See fig. 2 and attached poster in Powerpoint format).

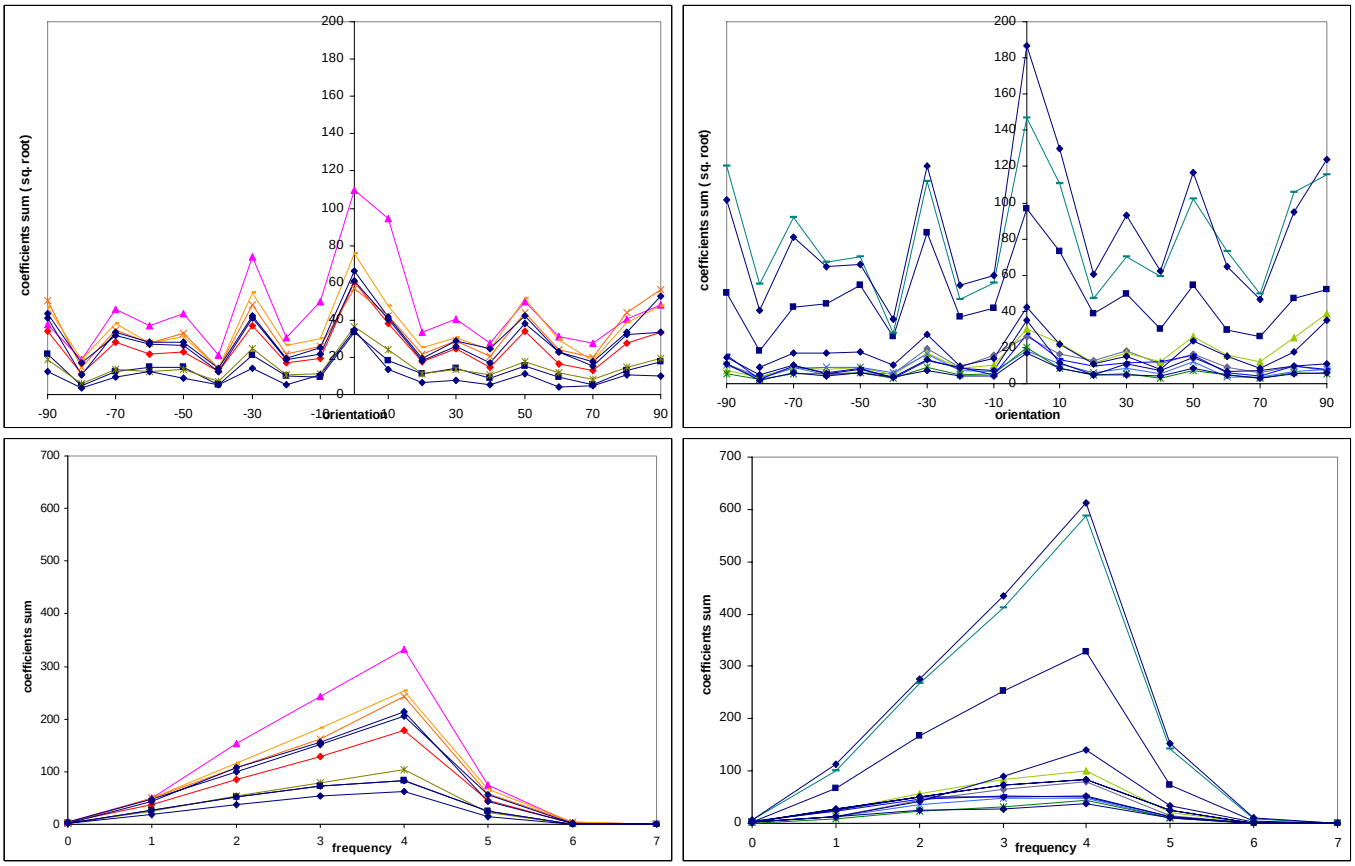

Figure 2. The weighting coefficients for orientation (upper) and spatial frequency (lower from the terrestrial learned basis functions for terrestrial images (left) and aerial images (right).

We have also started analyzing visual images from the aviation environment in terms of a visual detection model proposed by Ahumada (Ahumada, 1996;Ahumada and Beard, 1997;1998; Rohaly et al., 1997). This model has been applied to visual data sets in the terrestrial environment and well predicts detection under many conditions. The model estimates how well the detection of objects will be impaired by the background. It accomplishes this with some simple filtering algorithms that compute the contrast masking energy of the background. The model produces a measure of sensitivity (d') that should predict relative behavioral detection thresholds. Thus different aviation environments can be measured and predictions made about how difficult these environments are for detection relative to one another.

The next phase of this study will be to test the predictions of the model in behavioral detection studies both on simplified computer simulations and more advanced tasks in the flight simulator that include distractions and variables from the flying tasks.

Learning to see

As a preliminary step towards training pilots to see, we have developed a simple reference card for use in the cockpit (see appendix). This card illustrates the apparent sizes of typical small airplanes (e.g. Cessna 172) and airliners (e.g. Airbus A-320) at different distances from 2 miles to ½ mile. This card can be used by the pilot to estimate the approximate size of a known but undetected target. It is hoped that this aid will help improve target detection and would be especially useful for low time pilots and during private pilot training.

We have also begun to develop a preliminary version of the final training product,

an interactive program that will educate and train pilots in the issues of visibility.

The first part of the program will introduce the concept of visibility in the context of the aviation environment. The second part will introduce 4 problem areas:1) learning to see; 2) VFR fight into IMC; 3) background masking; and 4) flat light. The third part will be interactive training in two main areas 1) learning to see other aircraft and 2) learning to evaluate the visual environment. The first part will cover judgments of distance, direction, altitude, flight path and orientation. The second part will cover judgments of background masking effects, atmospheric haze , VFR into IMC, and flat light recognition.

We have completed a preliminary version of the part of the program that trains pilots how to judge the appearance and elevation of aircraft traffic given the distance, direction of flight, and altitude from a simulated traffic call. The trainee is also given an altimeter readout and a directional gyro readout in order to provide information to compute relative orientation and altitude. The trainee's task is to pick the visual scenario that matches the traffic call, out of four possible scenarios that appear on the screen simultaneously. The trainee is also provided feedback to improve learning.

The final main deliverable product should be available by the end of the 3-year funding period (March 31, 2006).

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Aid for Judging the Apparent Size of Aircraft

Print this sheet, cut out the 3 X 5 reference card, and fold it in half on the dotted line. Measure the calibration mark on the bottom and see if it measures one inch. View the card from 18 inches if the line measures one inch. If not, mutiply the standard viewing distance (18") by the length of the line. That should be your correct viewing distance for the card (example: line length = 0.8 inches. 18 X 0.8 = 14.4 "; In this case your viewing distance would be 14.4 inches).

Know what to look for!

Approximate appearance of an airliner and a small single engine aircraft

(view at a distance of 18")

2 Miles **1 Mile** **1/2 Mile**

Front

Fold Here

To quickly detect traffic, pilots should know the apparent size of aircraft at various distances. This card can be used as a reference in the cockpit and to help pilots learn target size.

To view the card, hold it at a distance of 18 inches from the eyes. The sizes of the images approximate those produced by actual aircraft (a Cessna 172, and an Airbus 320). These aircraft were chosen as examples of small aircraft and airliners.

Note that the actual appearance and visibility of real aircraft will vary with color, weather, direction of travel, type of aircraft and other factors.

Developed by Dr. Michael Crognale; Send any questions or comments regarding this aid to: Dr. Crognale (mikro@unr.edu); or The Federal Aviation Administration, General Aviation and Commercial Division; (AFS-800), Room 835, 800 Independence Avenue, S.W., Washington, DC 20591,Phone: 202-267-8212; or General Aviation Human Factors Program Manager (william.krebs@faa.gov).

Back

Cut Out

1 inch

Calibration