Visibility in the Aviation Environment

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Many general aviation accidents can be partly attributed to failure of the pilot to detect other aircraft and/or conditions of reduced visibility resulting in controlled flight into terrain (CFIT) or even ground based accidents and runway incursions. This present project (currently at the end of its second year) is aimed at better understanding visual limitations imposed by factors in the aviation environment and to provide interactive educational materials with the aim of teaching pilots how to deal with these limitations and to better recognize unsafe visual conditions.

Introduction

General

The present report represents the second annual report for this project due to a late funding date of April 2003 and covers activity from April of 2004 until October of 2005. We will describe below several important results and accomplishments during this period.

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 wo of which are considerd here.

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. The solution to these tasks are easily calculated from known relationships. Training is required however for pilots to perform quickly and automatically.

Last year we developed a cockpit aid for training pilots to better judge distance and size of targets. This product was met with great enthusiasm and I am still getting correspondence requesting this product for flight training at flight schools in Civil and military contexts.

We will describe below the current design of additional educational 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.

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). Last year we 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. Have reported these results last year.

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 provide input to educational materials described below.

Accomplishments and Results

Simulator

Last year we completed construction of a flight simulator with extended visual display. This year we have made progress towards programming the simulator to provide appropriate backgrounds and weather phenomenon for detection experiments.

Fig. 1 Simulator for detection experiments.

Aviation Images

Last year we 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. We also analyzed these images using sparse coding algorithms and compared the characteristics of the aviation environment with those of the terrestrial environment and found that they differ in many important respects. The analysis has allowed us to quantify those differences.

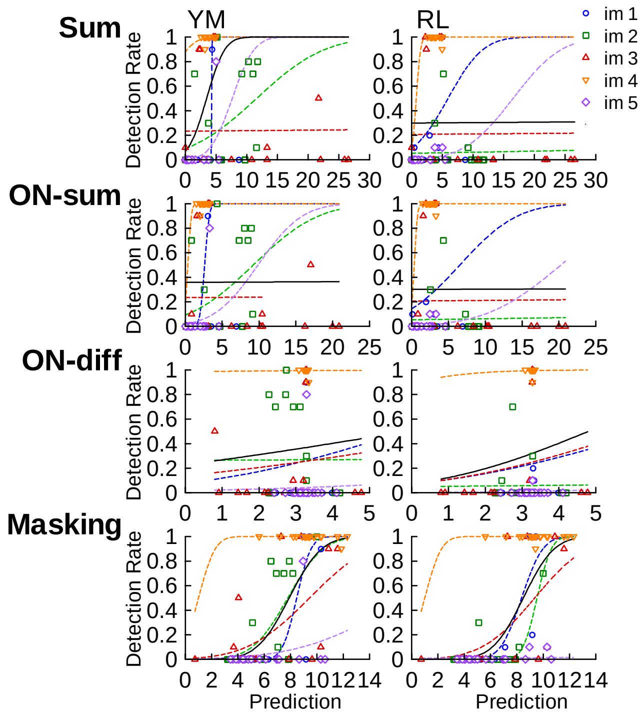


Figure 2. Detection data and model fits for 5 different images from the aviation environment.

This year we have developed three related models of detection based on the sparse coding information and compared them with another model of detection (Ahumada and Beard) as well as actual detection performance data collected in our lab (see fig.2).

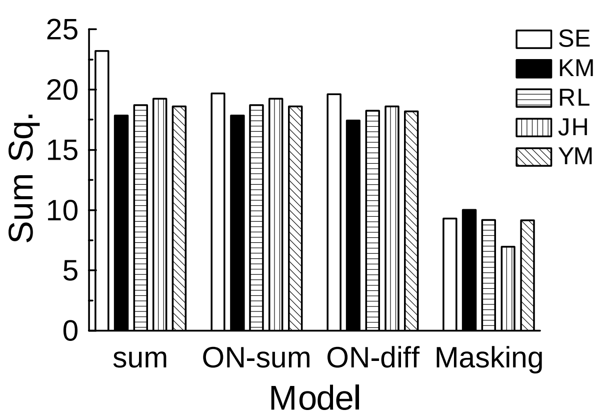


Figure 3. Sum of squared error for fits of four different models of detection with actual detection data for 5 different subjects. The masking model (Ahumada and Beard) appeared to better account for the data.

We found that although the image analysis based on sparse coding was quite useful for quantifying the image characteristics, the models developed using the algorithm did not provide significant advantage over the mathematically simpler Ahumada and Beard model (see figs. 2 & 3)(Mizokami & Crognale, 2005b).

The next phase of this study will be to test the predictions of the models against behavioral detection results obtained in a more realistic aviation setting include distractions and flying tasks provided by the flight simulator.

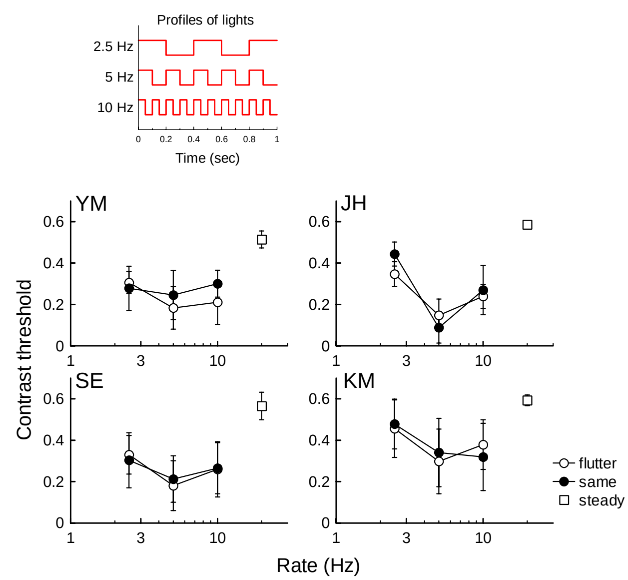
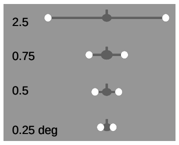


Figure 4. Effects of strobe frequency on detection shown for 4 subjects.

Another practical issue in aviation detection is how to improve aircraft detection through the use of lights. Strobe lights provide a means for improving detection of an aircraft. Some evidence suggests that rate of flash and the percept of apparent motion created by flashing the lights a synchronously might improve detection over a traditional synchronous paired strobe flash pattern. We tested this directly in a series of experiments that required detection of flashed lights on noise backgrounds that emulated that found in the aviation environment. We found an obvious improvement in detection for flashing strobes vs. steady lights but little effect of degree of synchrony, rate of flash and distance between strobes over a range relevant for aircraft detection (see figs. 4-7) (Mizokami and Crognale, 2005a).



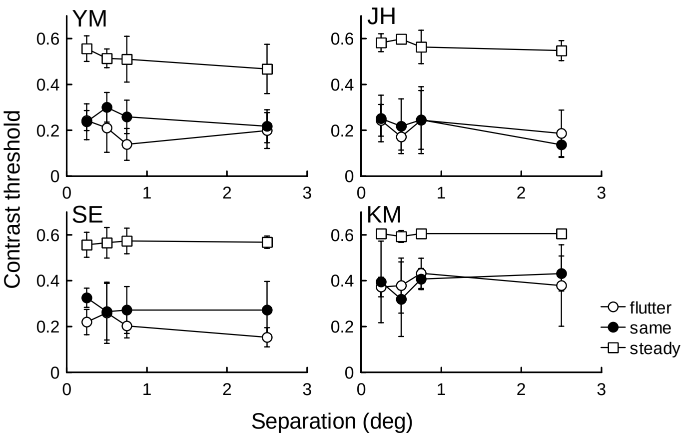
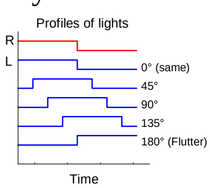


Figure 5. Effects of separation distance on detection of steady, and synchronous and asynchronous strobes.



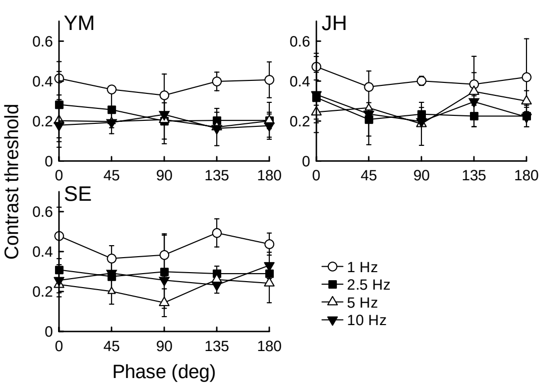


Figure 6. Effects of phase of synchrony on detection for 3 subjects. Phase has little effect.

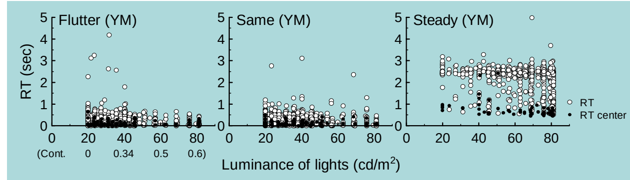


Figure 7. Effects of mode of flash (asynchronous flash, synchronous flash and steady) on reaction time to detection.

Learning to see

Last year we 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. Feedback on the use of this card has been quite positive and we will continue to provide it to pilots as requested.

The first part of the program introduces the concept of visibility in the context of the aviation environment. The second part introduces 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).

References

Ahumada A.J (1996) Simplified Vision Models for Image Quality Assessment. SID International Digest of Technical Papers, Volume XXVII, May, 397-400.

Ahumada A.J. & Beard B.L. (1997) Image Discrimination Models Predict Detection in Fixed but not Random Noise. JOSA A, 14, 2471-2476.

Ahumada A.J. & Beard B.L. (1998) A simple Vision Model for Inhomogeneous Image Quality Assessment. SID Digest of Technical Papers XXIX, paper 40.1.

Field D.J. & Brady N. (1997) Visual Sensitivity, Blur and the sources of Variability in the Amplitude Spectra of Natural Scene. Vision Research 37, 3367-3383.

Khatwa R. & Roelen A.L.C. (1996) An Analysis of Controlled-flight-into-terrain (CFIT) Accidents of Commercial Operators 1988 through 1994, Flight Safety Foundation, Pilot Safety Digest, Special Issue, April-May.

Krause R.R (1995) Avoiding Mid-Air Collisions. S.S. Krause, Tab Books.

Mizokami Y. & Crognale M.A. (2005a) Detection of dual flashing lights. *Annual meeting for the Vision Sciences Society*, Sarasota, FL.

Mizokami Y. & Crognale M.A. (2005b) Detection model predictions for aircraft targets on natural backgrounds. European Conference on Visual Perception.

O'Hare, D. & Owen D (2002) Cross-country VFR crashes: pilot and contextual factors.. Aviation Space and Environmental Medicine (73) 363-366.

Olshausen, B.A., & Field D.J. (1996). Emergence of Simple-Cell Receptive Field Properties by Learning a Sparse Code for Natural Images. Nature, 381, 607-609.

Olshausen, B.A., & Field D.J. (1997). Sparse Coding with an Overcomplete Basis Set: A Strategy Employed by V1? Vision Research, 37, 3311-3325.

Rohaly A.M., Ahumada, A.J., Watson A.B. (1997) Object Detection in Natural Backgrounds predicted by Discrimination Performance and Models. Vision Research 37, 3225-3235.

Simoncelli, E.P & Olshausen B.A. (2001) Neural Image Statistics and Neural Representation, E.P. Annual Reviews of Neuroscience, 24,1193-1216.

Volpe (1994) Controlled Flight Into Terrain (CFIT) Report, 1983-1994