P-33: Identification of Simulated Targets as a Function of Target and Background Blur

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Abstract

Simulated imagery was used to determine the effect of target and background blur on target identification performance. An interaction between these two variables was found, indicating that greater image detail may not improve performance, and hence may not be required in applications for which high-resolution databases are not readily available.

1. Introduction

Even when display resolution is high, database limitations, or inherent limitations in the resolution of the sensor systems being simulated, may limit the spatial detail of simulated imagery. The result can be resolution mismatches between, for instance, terrain textures and 3D visual targets, which may reduce both simulator realism and target detection or identification performance.

The displays used to present FLIR imagery in a real aircraft are relatively small and have a much higher resolution than the displays used for the full-field, out-the-window view in most flight simulators. This higher resolution allows highly detailed models to be displayed. However, flight-simulation databases do not usually provide high detail, and the result can be a difference in detail between the model and the background. In general, the approach in this situation has been to display all of the detail available, under the assumption that higher detail will outweigh any potential negative effects associated with decreased realism. This approach also assumes that increased detail necessarily improves performance on target identification tasks, whether or not target and background detail is similar.

In the present study, we have assessed target identification for various levels of target and background blur, under the assumption that an interaction between these two variables (e.g., a greater decrease in performance for one level of background blur than for another) might suggest limits on the spatial detail that is necessary to display effective simulator imagery.

2. Methods

Observers. The eight observers varied in age from 18 to 30 years. All observers had normal or corrected to normal vision as determined by the acuity, binocular vision, color vision and phoria measurement tasks of the Optec Vision Tester (Stereo Optical Co., Inc., Chicago, IL).

Stimulus and Apparatus. The test stimuli consisted of a test target superimposed on a background image (see Fig. 1). The target images were right- or left-facing versions of an M1-tank model. The background was obtained from a standard flight simulator database. Imagery from a FLIR targeting pod may originate from either an IR sensor or a CCD camera. In order to obtain imagery that was somewhat representative of both of these viewing modes, the luminance values of each background and test target image were inverted (i.e., graylevels 0, 1 , 2, were changed to 255, 254, 253, ...).

The blur of the tank and the background were varied independently. Gaussian image blurring was performed using Adobe Photoshop. The blur levels used for the background were

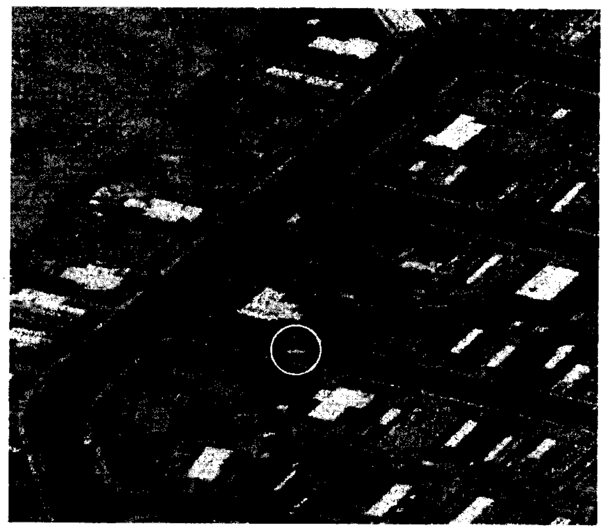

Fig. 1. An example of a test stimulus used in the present study. The circle indicates the location of the tank, and is not a part of the stimulus.

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14. ABSTRACT

Simulated imagery was used to determine the effect of target and background blur on target identification performance. An interaction between these two variables was found, indicating that greater image detail may not improve performance, and hence may not be required in applications for which high-resolution databases are not readily available.

15. SUBJECT TERMS

Simulated targets; Targets; Background blur; Simulated imagery; Target identification; High-resolution databases; Display resolution; Sensor systems; Simulation; Spatial detail; Terrain textures; Simulator realism; Identification; Displays; Simulator imagery; Performance

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0 (original tank model), 0.5, 1.0, 5.0, 10.0, and 20.0 pixels. The blur levels used for the target were 0.0, 1.25, 1.5, 2.0, 2.5, 3.0 and 3.5 pixels. The full set of background and target (left-facing only) images used in the present study are shown in Fig. 2. The degree of blurring was further quantified by obtaining the Fourier transform of each of the target and background images. Targets, both left and right facing, were superimposed on each of the six backgrounds, for a total of 84 test stimuli.

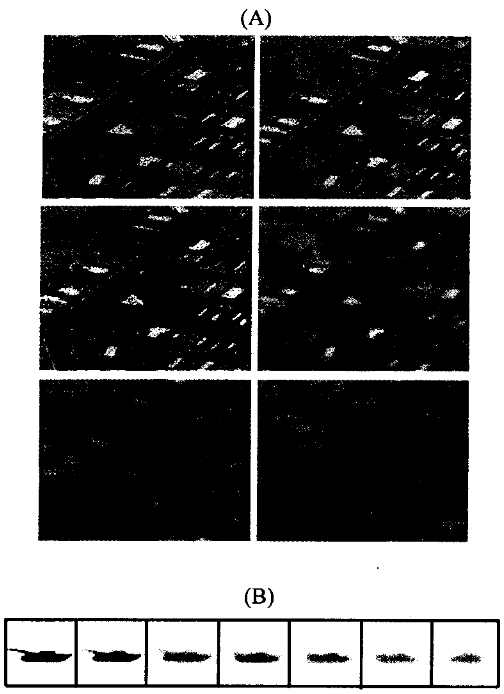

Fig. 2. (A) Each of the six blur levels for the background target, and (B) each of the seven blur levels test targets shown for each of the seven blur levels.

The size of the background was 114 mm (H) × 102 mm (V) and subtended 6.5° × 5.8° at a viewing distance of 1 m. All test stimuli were presented on a 6" × 4", 640 × 480-pixel, LCD display (Earth Computer Technologies, Model MTR-EVUE-6.5). The display had pixel characteristics similar to FLIR displays used in operational aircraft.

Procedure. The images were presented in random order. The observers were asked to indicate, by a left- or right-mouse click, whether the tank was facing left or right. Each image was presented for 1 sec and the observer had an unlimited time to respond. Each practice and experimental session consisted of 84 trials and lasted about 3 minutes. A total of ten sessions were run for each observer.

3. Results

Shown in Fig. 3 is the proportion of targets that were correctly judged to be facing either left or right, as a function of background blur, for each of the seven levels of target blur. The proportion of correct responses generally increased with increases in background blur, for all levels of target blur. The overall increase was somewhat greater, however, for the mid-range of target blurs. The proportion of correct responses generally increased with decreases in target blur, as did the proportion correct associated with 0-background blur for each level of target blur. A two-way, repeated measures ANOVA indicated significant effects of Target-Blur ($F_{6,42}$=40.2, p<0.001), and Background-Blur ($F_{5,35}$=9.7, p<0.001), as well as a significant interaction between these two variables ($F_{30,210}$=1.86, p=0.006).

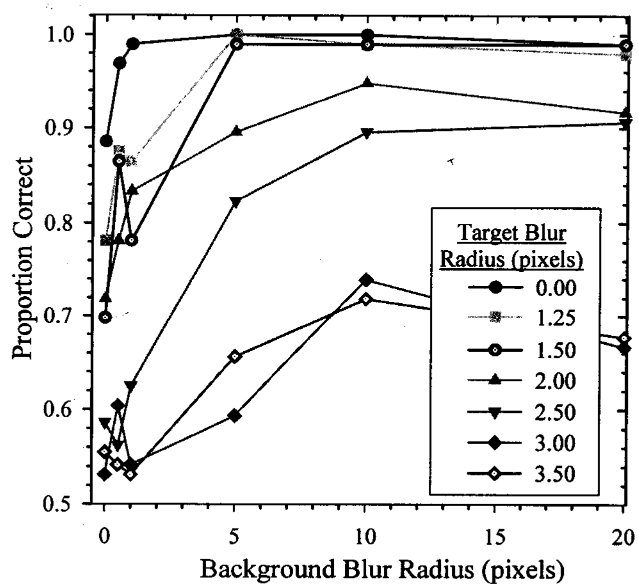

Fig. 3. Target identification performance as a function of background and target detail.

Shown in Fig. 4 are the Fourier transforms, plotted on a log-log scale, for the test backgrounds and targets. Linear functions have been fitted to each transform using a least-squares criterion. For the target transforms, the fitted functions have different slopes but tend to converge at the higher spatial frequencies. For the background targets, the fitted functions have similar slopes, and measured amplitudes generally decrease as amount of blur increases.

4. Discussion

The present study was motivated by the requirement to develop and evaluate a FLIR simulation for integration into the Distributed Mission Training system at the Air Force Research Laboratory, Mesa, Arizona. A perceptual issue of general concern in most high-performance flight simulators is the difference in resolution between 3D targets and the associated background imagery that is typically of much lower resolution. Although the relationship between target and background imagery has been considered [10], we know of no attempt to assess both target and background detail, and to assess any interaction between these two variables.

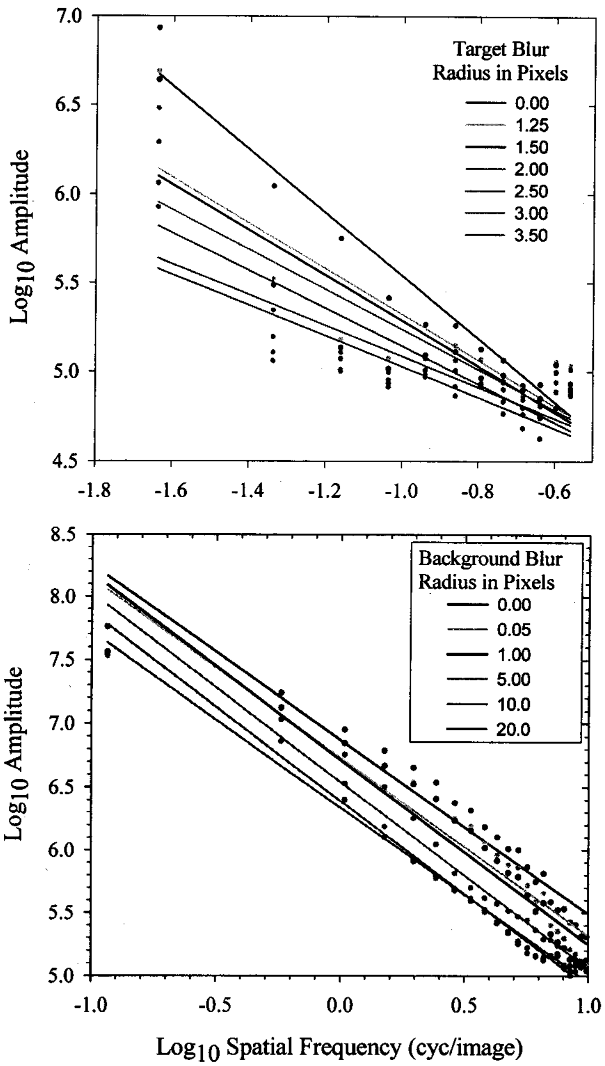

Fig 4. Fourier transforms of the target (top) and background (bottom) stimuli. In both graphs, the order of the plotted functions is the same as the order of the conditions shown in the legends.

It might be expected, in the context of the present study, that target identification would be related to the difference in the spatial-frequency content of the target and background. The data of Fig. 2 show that increasing the blur of the background resulted in an increase in target identification for all targets tested. The 0-blur target was easily identified at all levels of background blur, suggesting that its spatial detail was significantly higher than that of the background. On the other hand, the most-blurred targets (blur-radius = 3.0 and 3.5) were not well identified, especially for lower background blurs, suggesting that the levels of target and background blur were more similar under those conditions. These two aspects of the data of Fig. 2 also effectively describe the significant interaction between target and background blur that was found by the statistical analysis. It may be possible to select targets and backgrounds for which this interaction does not occur, but such discretion is not an option in most flight-simulator applications. Thus, it should be assumed that a relatively complex relationship will exist between visual identification performance and the spatial detail of the targets and backgrounds used in FLIR simulations.

The relationship just described between target and background detail may be further complicated by the nature of the Fourier spectra shown in Fig. 3. This was an applied study, and so target and background images were processed and displayed as they would be in operational flight simulators. For instance, we first blurred our targets and then displayed them on the device of interest, rather than displaying the targets and then blurring them by reducing the resolution of the display device. One consequence of this choice is that image blur may interact with the sampling properties of the display device. The changes in slope for the target spectra, along with their convergence at high spatial frequencies suggest that this is in fact the case. The background spectra seem to be better behaved, but they too do not show the relative low-pass characteristics that are normally associated with image blurring.

Most of the perceptual research involving FLIR imagery seems to have been performed in the context of either testing particular visual models [8,9] or characterizing aspects of IR imagery that may be relevant to visual performance [1,2,4,5]. The data of Driggers *et. al.* [3], however, show some similarity to the present data. Although those authors do not discuss it, their data show a non-monotonic relationship between visual performance and sampling, which varies as a function of image blur. Their data are significantly different from the present data, however, thus reinforcing our previously stated conclusion that target and background characteristics may be expected to have complex effects on visual performance.

As noted above, relatively few studies have been primarily concerned with the visual properties of FLIR imagery. In general, the approach has been to collect data to test a specific model, rather than to apply a number of models to data that is generally accepted to be valid and relevant to FLIR issues. The present data are generic in the sense that target and background detail is varied directly and those variations are quantified. Data of this type should be useful for testing a wide variety of visual or detection models of FLIR, and related, imagery. While we believe that we have outlined an appropriate procedure for generating and testing generic FLIR imagery, the present data are only preliminary. A more complete visual assessment of FLIR imagery would include 1) a more accurate quantification of image properties, which might be done, for instance, by using more general convolution routines to blur the imagery, 2) a more complete assessment of image properties, such as luminance variations within targets, or contrasts between target and background [6,7], 3) a generalization of the present results to a more diverse set of target and background images, and 4) a perceptual evaluation of realistic and quantified FLIR imagery obtained, for instance, from videotaped real-world imagery or FLIR simulations.

In most flight-simulator applications, the goal is to present a level of visual detail consistent with that present in the real-world environment that is being simulated. As a practical matter, however, the detail of localized targets is often greater than that of the much larger background terrain. The present data suggest that, in order to provide an accurate simulation, target detail should be chosen based on the background detail that is available in a given application. This approach may also reduce the level of target detail that must be simulated, thus reducing computational demand.

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