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PREDICTOR SYMBOLOGY IN COMPUTER-GENERATED PERSPECTIVE DISPLAYS

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SUMMARY

An advanced display format for the four-dimensional commercial aircraft approach-to-landing is evaluated. The desired curved and descending approach path is presented by displaying the perspective image of a tunnel. Attention is focussed on the predictor symbology, superimposed on the tunnel image. A perspective three-dimensional predictor symbol, providing future position, as well as future attitude information, is compared with a flat two-dimensional version, which only provides the future position. In addition to this, the predictor displays the actual airspeed as well as the desired airspeed, prescribed by the four-dimensional path.

Results show that the three-dimensional predictor symbol outperforms the two-dimensional predictor in following the trajectory in a moderate-to-heavy turbulent environment, which is manifested in a significantly lower roll-acitivity and a better following accuracy. Futhermore, accurate manual true airspeed control was obtained without affecting the main task performance significantly.

INTRODUCTION

Computer-generated pictorial displays facilitate the integration of control information in a format, analog to the "through-the-windshield" visual field. The tunnel display, in which the three-dimensional approach path is displayed as a winding descending "tunnel-in-the-sky" is found to be suitable in particular for following complicated curved trajectories. It is shown in a previous work [1], that pictorial displays without further augmentation, yield impaired system damping due to the lack of peripheral visual cues. It is also shown that superimposed predictor symbology furnishes the system with the necessary damping cues.

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In this paper the effectiveness of more complex predictive information is explored. A perspective aircraft symbol is shown, predicting the vehicle position as well as vehicle attitude angles, at a given time in the future. Forward velocity cues are derived from predictor-distance variations. Since, for a fixed prediction time, the predictor-distance is proporti[illegible] the vehicle velocity, the predictor symbol image will apparently [illegible] increased velocity and grow with decreased velocity. The usef[illegible] these changes in predictor distance for controlling the true airspe[illegible] [illegible]stigated.

DISPLAY FORMAT

Fig. 1a shows the tunnel display with perspective predictor symbol. The vehicle is to the right of the tunnel and banked to the left, as shown by the inclined horizon (a). The curved tunnel trajectory, with a square 300 x 300 ft. cross-section, is indicated by the four corner lines (b). The solid square (c) is a cross section of the tunnel a distance $D_0 = T/V_0$ ahead of the vehicle, (in Fig. 1a $D_0 = 900$ ft), where T is the prediction time and V_0 the nominal desired true airspeed. The predictor symbol (d) is at distance D ahead where D is predicted from the actual vehicle velocity. The corresponding tunnel cross-section at D is indicated by the four bright blinking tick-marks (e). Since the solid square corresponds to the desired velocity and the tick-marks to the actual velocity, the velocity is controlled by matching the tick-marks to the square. Fig. 1b shows the display with two-dimensional predictor at a nominal distance of 2000 ft.

RESULTS

The dynamics of a control-augmented DC-8 aircraft were simulated, with either automatically or manually controlled throttle. The nominal true airspeed was 243 ft/sec. The control task was to follow the trajectory in the presence of random appearing gust disturbances. Fig. 2 shows typical results of one of four subjects. Fig. 2a shows that, both for the three-dimensional as well as for the two-dimensional predictor, the covariance of the lateral deviation increases with the nominal predictor-distance. However, the three-dimensional predictor yields a better tunnel following accuracy. Fig. 2b shows a general decrease in the covariance of the roll-rate with increased predictor distance. The advantage of the three-dimensional predictor is clearly demonstrated by the significantly lower roll-activity. In Fig. 2 the results for auto and manual throttle are compared. Manual velocity control was accomplished without affecting the following accuracy or roll-activity, significantly.

CONCLUDING REMARKS

Predicted attitude information, provided by the more complex three-dimensional predictor symbol, is successfully utilized and contributes to improved system damping. Airspeed control by using variations in the predictor distance is proved successful. The subject of further research will be the choice of predictor law and filters considering noisy on-board measured sensor data.

REFERENCES

1. Grunwald, Arthur J., Robertson, James B., and Hatfield, Jack J.: Experimental Evaluation of A Perspective Tunnel Display for Three-Dimensional Helicopter Approaches. AIAA Journal of Guidance and Control, Scheduled for Publication, Oct. 1981.

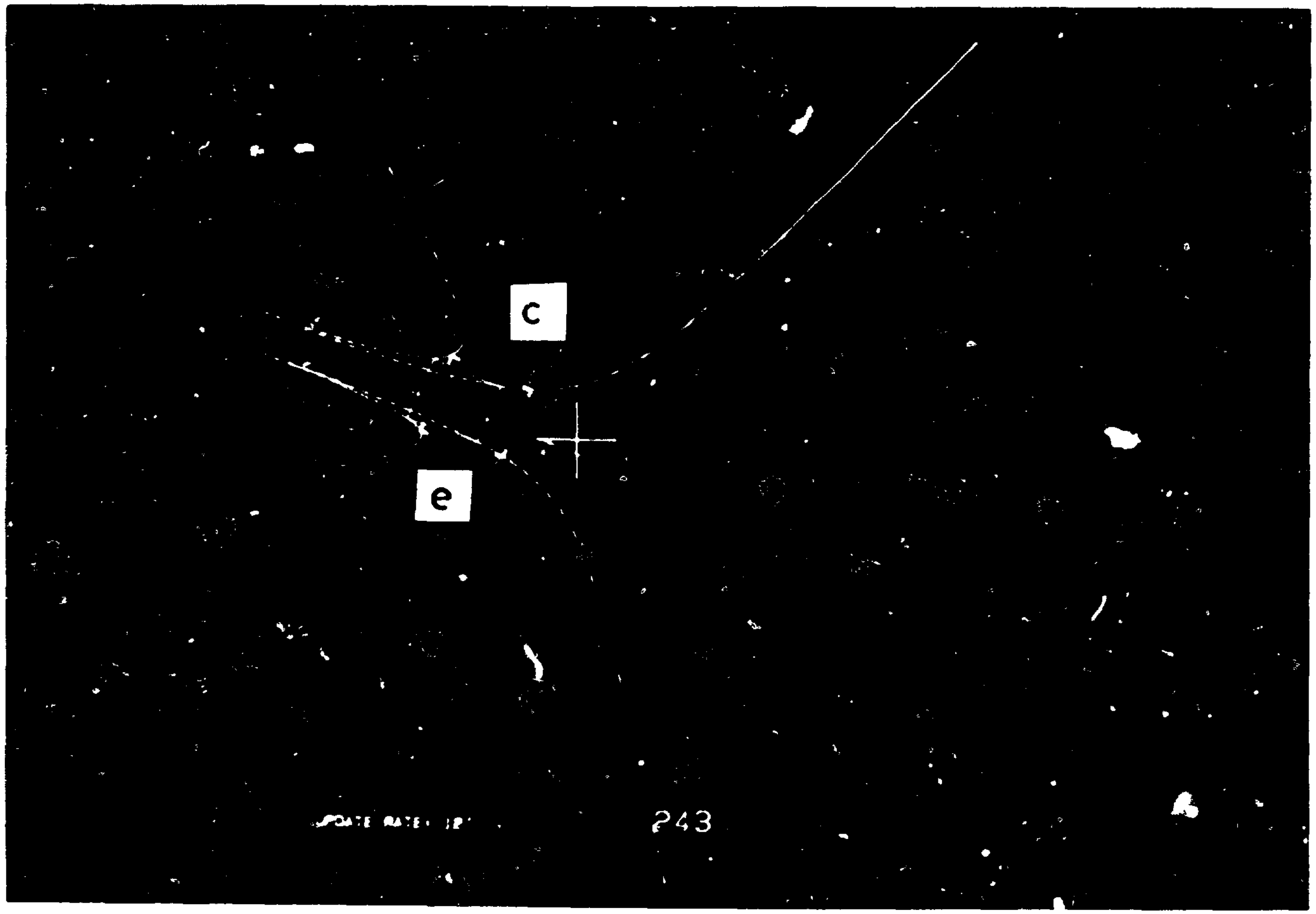

Fig. 1b: Tunnel Display with Two-Dimensional Predictor Symbol (D_o = 2000 ft).

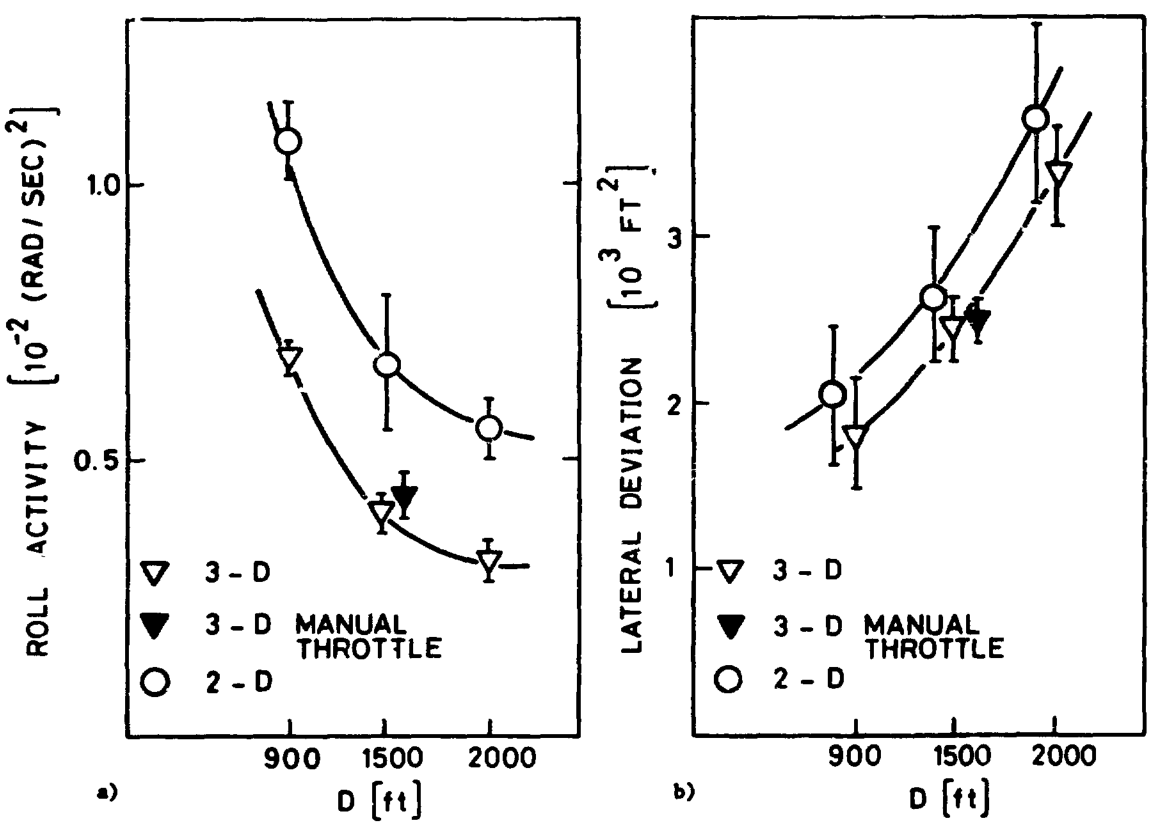

Fig. 2: Results for Tunnel Following

a) Covariance of Roll-Rate

b) Covariance of Lateral Deviation.

Average and ±1σ bars of 8 runs of 128 seconds duration.