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COMPUTER-AIDED MANUAL TRACKING

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SUMMARY

A scheme has been developed to assist the human operator by augmenting an optic sight manual tracking loop with target rate estimates from a computer control algorithm which can either be a Kalman Filter or an α, β, γ Filter. The idea is for the computer to provide rate tracking while the human operator is responsible for nullifying the tracking error. A simple schematic is shown to illustrate the implementation of this concept.

A hybrid real-time man-in-loop simulation was used to compare the tracking performance of the same flight trajectory with or without this form of computer-aided track. Preliminary results show the advantage of computer-aided track against high speed aircraft at close range. However, good tracking before target state estimator maturity becomes more critical for aided track than without. Results are presented for a constant velocity flight trajectory.

I. INTRODUCTION

It is a widely accepted fact that the human, while acting as a control element, not only exhibits a variety of nonlinear and time-varying behavior but also posesses unique adaptive and learning capacity. These characteristics make the human an indispensible part of many control and tracking missions. Due to the inherent limitation of a slow reaction time and a "noisy" output of the human tracker, tracking performance deteriorates rapidly when the target trajectory results in high angular rates and accelerations, for example, in the cross-over region near the point of closest approach.

The idea of rate-aided track for an unmanned closed-loop tracking system has long been discussed in detail for example by Fitts (1). However, the application of this concept to the manual tracking system has not been so successful. This paper will present the concept, implementation and simulation of a rate-aided scheme to a manual tracking task.

Section II will show the track loop and the target state estimator (TSE) while section III will show how the aiding rates are generated by the computer, based on the information available in the TSE, as well as how these aided terms are introduced into the track loop controller. Section IV is experiment setup, Section V will present the simulation results for a constant velocity trajectory with and without the rate-aided feedback. Finally, Section VI presents our conclusions and recommendations.

II. OPTIC TRACK LOOP AND TARGET STATE ESTIMATOR

A typical single axis man-in-loop optic track system is depicted in the following block diagram, Figure 1. Whether the track is computer-aided or not depends on the on-off computer-aided switch position.

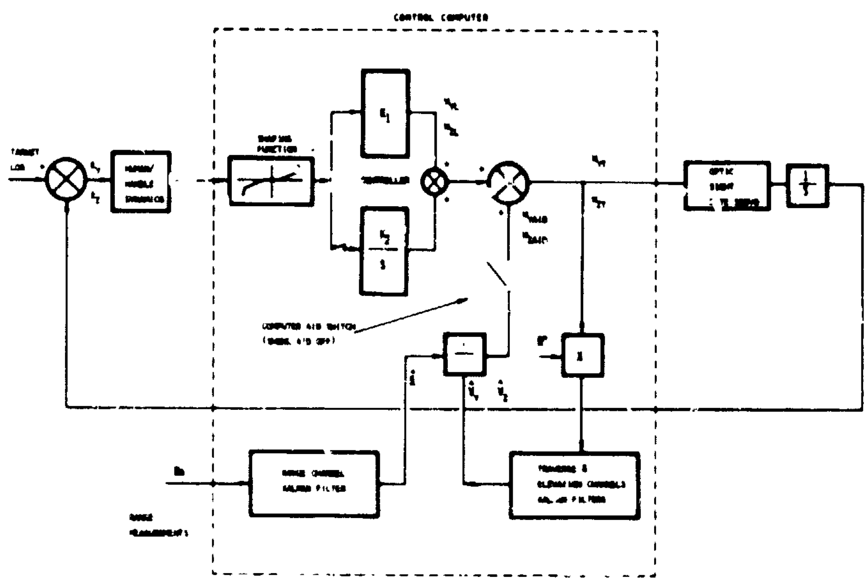

Figure 1. Optic Track Loop and Target State Estimation

Upon seeing an angular tracking error, which is the difference between the target line-of-sight and the optic sight center line, the human tracker outputs a rate command through a thumb transducer to the sight controller. In the present (baseline) case, the controller is a proportional plus integral element in the computer's software and in turn commands the sight servo to follow the target motion. Without any rate estimates to aid the human tracker, the target state estimator is outside the track loop and serves the function of generating target's, velocity and acceleration. It is this information that will be used to generate rate-aided feedback terms.

III. COMPUTER-AIDED RATE FEEDBACK

Based on the range measurement and the two angular rates of the optic sight, the target state estimator estimates the target velocity and acceleration at the end of the digital cycle in the instantaneous sight frame, under the assumption that the tracking errors are small. The outputs of the filtered quantities are range (R^*) end point velocity estimates (V_x^*, V_y^*, V_z^*) and acceleration (A_x^*, A_y^*, A_z^*). In order to generate the proper rates for augmentation to the track loop, the end point velocity estimates are first extrapolated to obtain the future target velocity one computer cycle time ahead and then rotated into the new instantaneous sight frame at the next cycle to obtain $\hat{V}_y$ and $\hat{V}_z$. Two filtered angular rates ($\hat{V}_y/\hat{R}$) and ($\hat{V}_z/\hat{R}$) are applied to the controller. This is the rate-aided term generation sequence in steady state. Since the filter takes a finite time to settle, including an aid term obtained from an unsettled filter can only degrade tracking performance. Even when the filter is fully matured, the abrupt adding of an aided term is too large a disturbance for the human operator to handle. Therefore, this computer-aided term is ramped into the track loop in about 2-3 seconds while the integral element in the controller is ramped out. We have learned from simulation experiments that good tracking and earlier filter maturity are critical to the tracking performance for aided track. A separate switch, therefore is provided for the human tracker to decide when to use this computer-aided tracking mechanism.

IV. HYBRID COMPUTER EXPERIMENT SET-UP

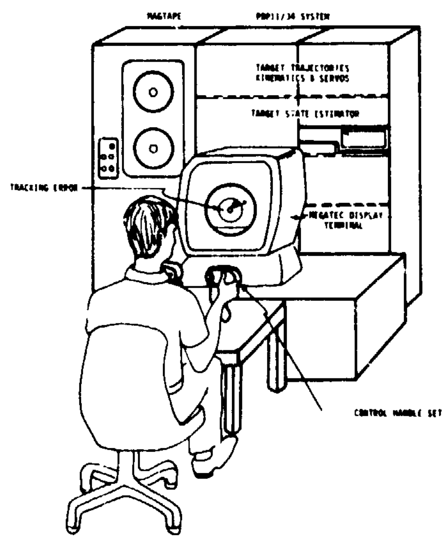

Figure 2. Real-Time Man-in-Loop Simulation

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The simulation facility as shown in Figure 2 consists of a PDP11/34 digital computer, a Megatek graphics display unit, a control handle which interfaces with the host computer via a DEC AR11 A/D converter and various supporting devices. The numerical computation, including system kinematics, servo response, coordinates transformation and tracking error generation, is done by the PDP11/34. The whole simulation is run in real time with a cycle time of 36 msec. The outputs, which are essential to the performance study, are stored in the main memory as they are computed and transferred later onto the disk. The predesigned target trajectories are stored on the disk and loaded into memory before the real time run starts. This is also true for all the initialization of the simulation as well as target display graphics. Whenever the tracking error is greater than the half field view angle, the run is terminated to simulate loss of lock.

V. SIMULATION RESULTS

The target model used in the simulated example is an incoming constant velocity aircraft flying at about 250 m/sec with the closest approach about 300 meters. The commanded rate outputs for human operator for both unaided and aided cases are shown in Figure 3. Similarly, the tracking errors are shown in Figure 4. The tracking is done by the same operator. It should be noted that the system loses lock near the cross-over for the unaided case.

VI. CONCLUSION AND RECOMMENDATION

1. The computer-aided track is not needed for low speed target but does help the operator to track a high speed target in the cross-over region.

2. Early tracking accuracy is essential for the target state estimator to have enough data of good quality to generate aided rates.

3. Research and development in this area will result in improved manual tracking performance.

VII. REFERENCE

1. Fitts, John M.: Aided Tracking as applied to High Accuracy Pointing Systems. IEEE Transactions on Aerospace and Electronic Systems. Vol. 9, No. 3, May 1973.

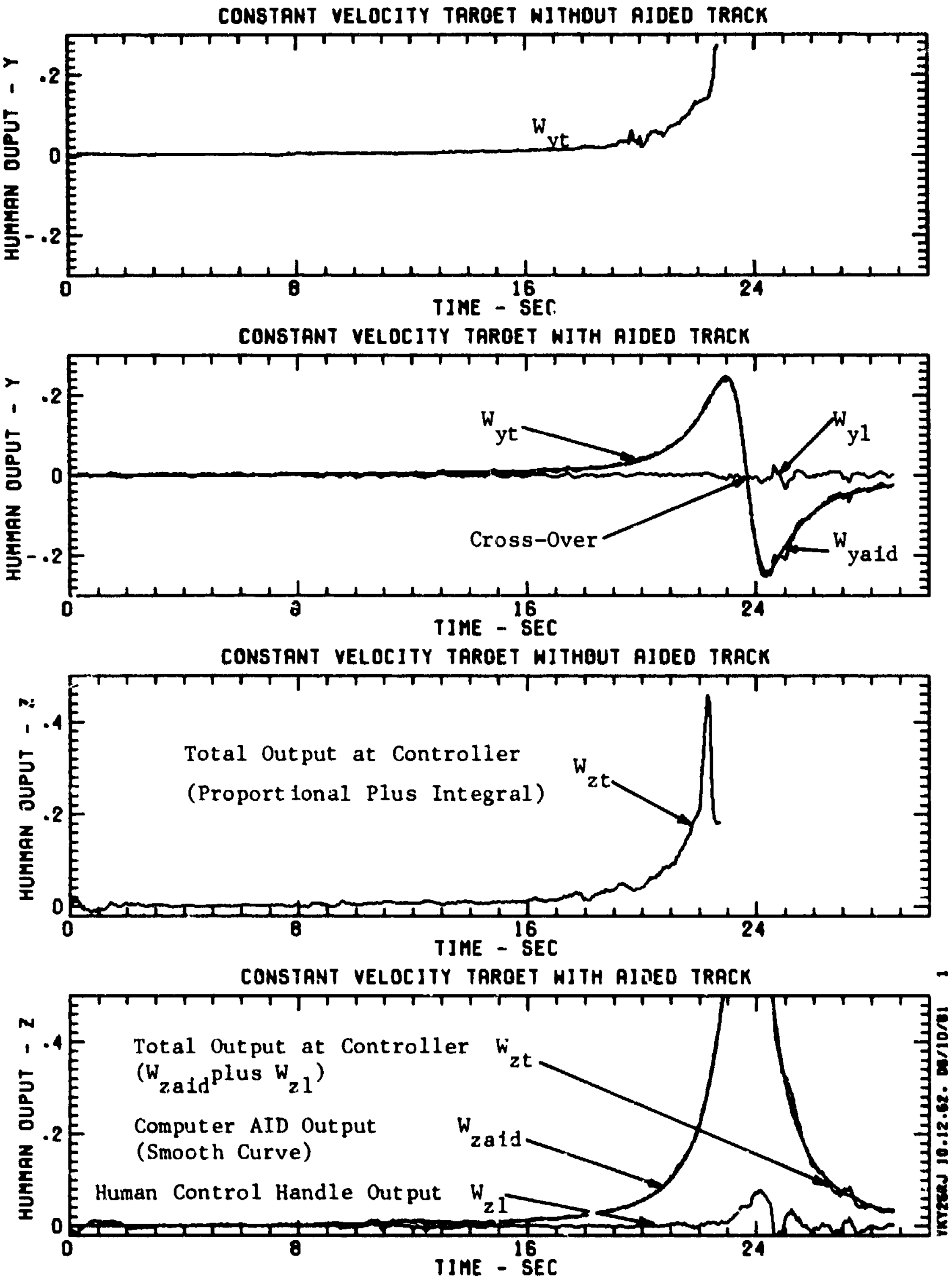

Figure 3. Human Output

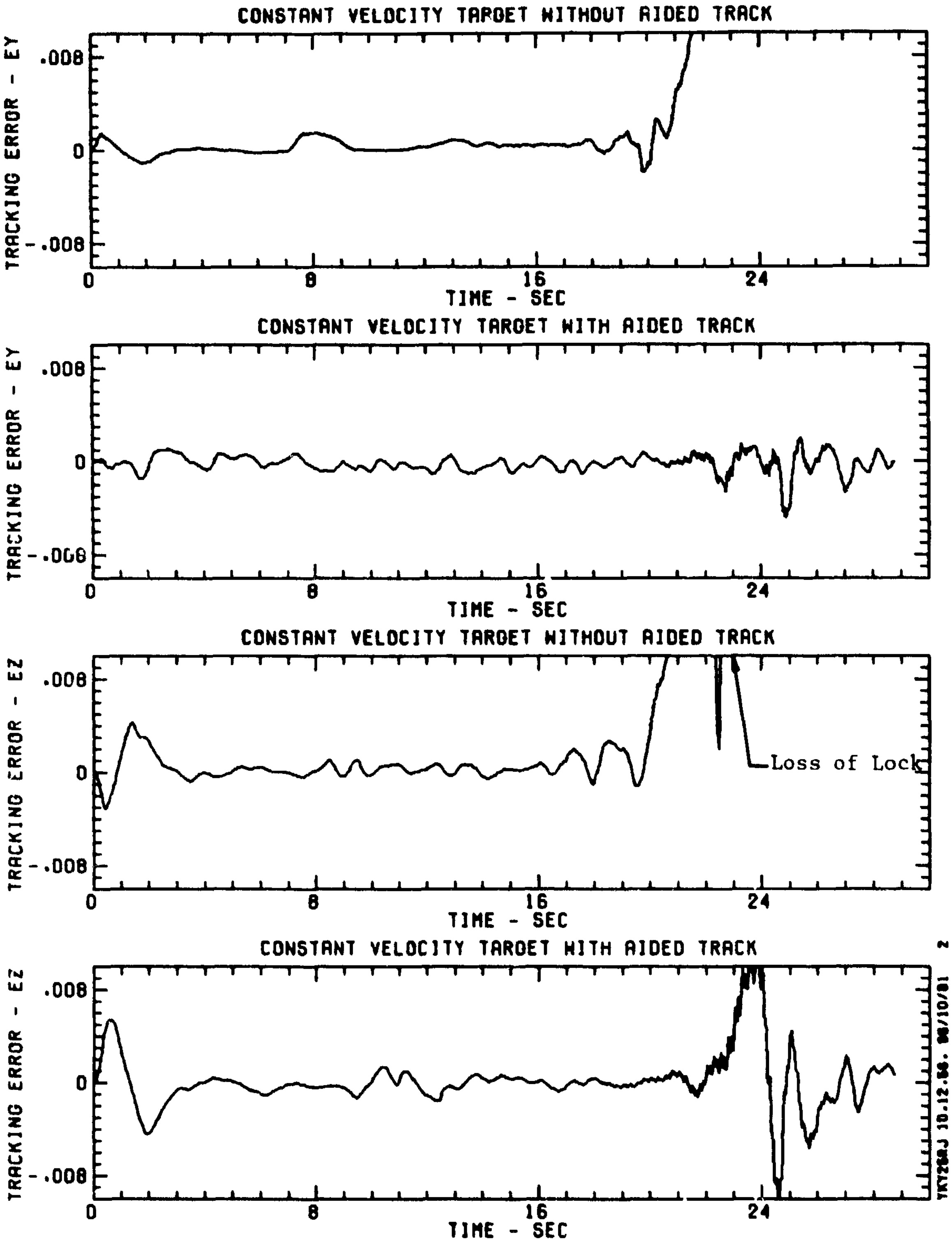

Figure 4. Tracking Error