A MOTION SENSING MODEL OF THE HUMAN FOR SIMULATOR PLANNING

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INTRODUCTION

The conventional use of simulators for flight research, be they moving base or fixed base, has involved an attempt at reproducing some aspects of face validity without determining either the requirements for such validity or the aspects of the simulation which are really important in either research or training. Limited knowledge of the physiological sensing mechanisms, especially for the perception of motion, has forced upon the simulation community an acceptance of "expert pilots'" opinions as the *sine qua non* of simulator design and acceptability. Yet, very rarely do two pilots agree on all aspects of a simulator's fidelity. With the development of better models of physiological processing of sensory signals and a framework for their use based upon modern control theory, we are now in a position to improve upon this situation for simulator planning. This paper describes a number of parallel research efforts (Ref. 1),which are being carried out by the Air Force Human Resources Laboratory, to (1) improve the basic physiological subsystems descriptions and (2) integrate these subsystems into a model for simulator planning. It is anticipated that such a model will not only aid in the planning of simulators but also possibly become a major portion of the simulator's drive logic.

CONVENTIONAL VIEW

Current simulation methodology is based upon an open loop strategy as depicted in Figure 1. The assessment, other than through pilot opinion, is typically on the basis of closed-loop control. Does the pilot "do the same thing" in the simulator as he does in the real aircraft? Since the adaptability of the human pilot makes such closed-loop performance criteria relatively insensitive to the simulation fidelity, they are not particularly convincing. The conventional method is to simulate the aircraft's flight equations in real-time on a computer and to use the aircraft state variables to drive separately a visual display, instruments, motion platform, sound system, and any G-cuing devices. Each of these systems is commanded to reproduce as accurately as possible the sights, sounds, and feel produced by the corresponding aircraft situation. The assumption is that the pilot will be provided the best overall simulation if he is presented with individual sensory modalities, each of which is tuned to reproduce the real world situation as best as possible within the limitations of cost and mechanical drives. Relatively little effort has been paid to the question of how to best compromise any one of the simulation modalities or how to best combine the

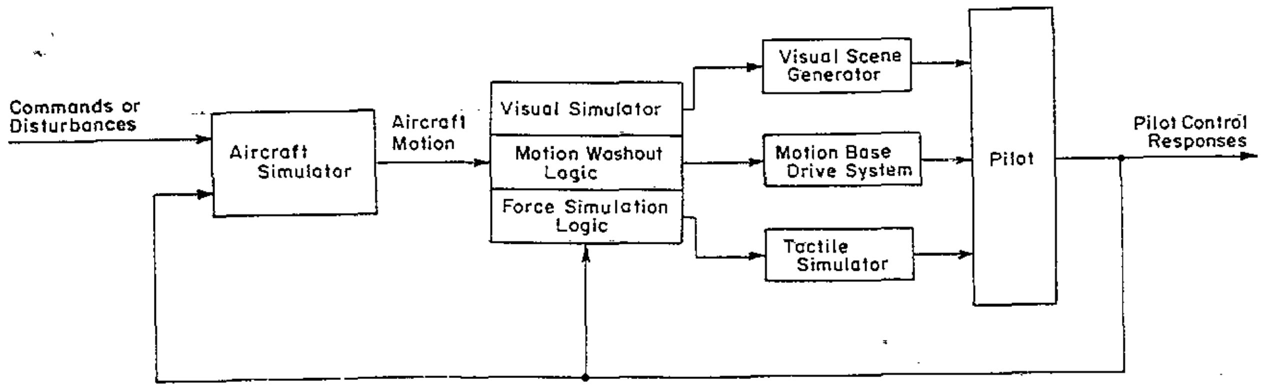

Figure 1. Current Simulation Design Method Based on Duplicating Aircraft Motion

different sensory input simulations to produce an overall effect which is better than that produced by working with them individually. For example, the question of the influence of moving visual fields on the requirements for low frequency cab motion drives is an important factor, one which is not addressed by this design philosophy. A limitation of the conventional design philosophy is, in our opinion, the concentration on faithfully reproducing aircraft motions and force rather than reproducing pilot sensations.

THE "PILOT SENSORY MODEL" APPROACH TO SIMULATOR DESIGN

If we assume that the goal of simulation is to produce the same sensations of motion and force in the pilot during the simulation as he would receive during actual flight, then one is led to a design configuration illustrated in Figure 2. Underlying this philosophy is the existence of an adequate model, the "multisensory motion sensing model of pilots" which predicts, in at least a statistical sense, the pilot's perception of spatial orientation based upon defined visual, motion, and force inputs occurring individually or in combination. This model is applied to the actual aircraft situation being investigated to determine what the pilot's perceptions would be in the aircraft. It is then also applied to the proposed simulator output to predict what the errors in perception would be. Simulator visual, motion, and G-cuing drive algorithms may then be designed to produce simulator output within the mechanical limits of the equipment which will minimize this error in perceived orientation. Clearly, the major weakness in this design philosophy is the lack of adequate multisensory motion sensing models. Attempts to remedy this situation are a part of our current research. As indicated in Figure 3, we are treating perceived orientation as an optimum estimator problem in which a Kalman filter estimates the perceived orientation based on the outputs of the various sensory systems each of which is assumed to have a characteristic dynamic response and associated additive noise. The models for sensation of angular velocity attributable to the vestibular senses are relatively well developed. Even complex motions, involving possibly contradictory information presented by the otoliths and semicircular canals, can be treated by such models (Ref. 2). Similar models for foveal visual inputs, which basically relate to instrument readings, have been developed and require only application of the appropriate fraction of attention divided to each instrument to be applied (Ref. 3). Peripheral visual information which leads to perceived changes in orientation or angular rate are being developed on the basis of work on visually induced motion (Ref. 4). The greatest area of uncertainty is in the processing of tactile and proprioceptive information. Data from these systems will be most important in determining stimulation and drive requirements for G-cuing devices, including G-seats, G-suits, and seat shaker systems. We are currently using both psychophysical and physiological data to try to develop both the high and low frequency characteristics of these sensory modalities and to achieve appropriate noise levels so

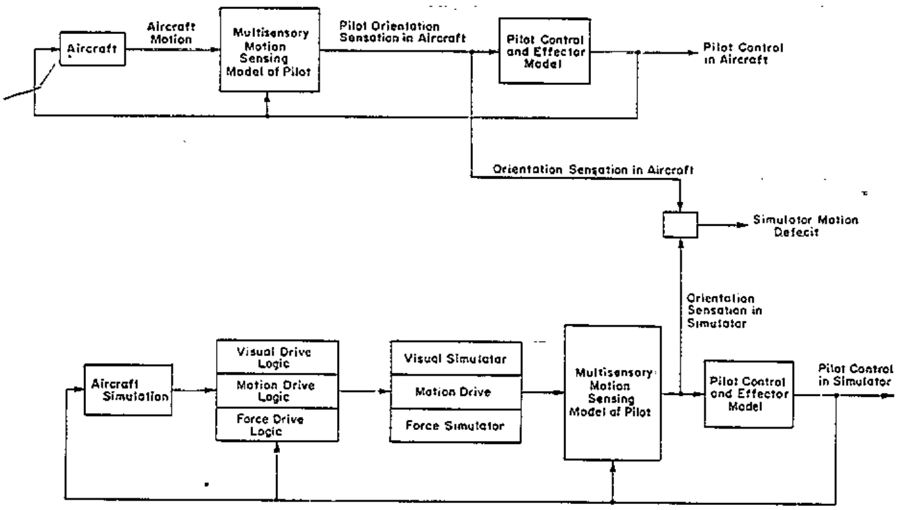

Figure 2. Schema for Simulator Specification and Control Based on Pilot Sensory Systems Models

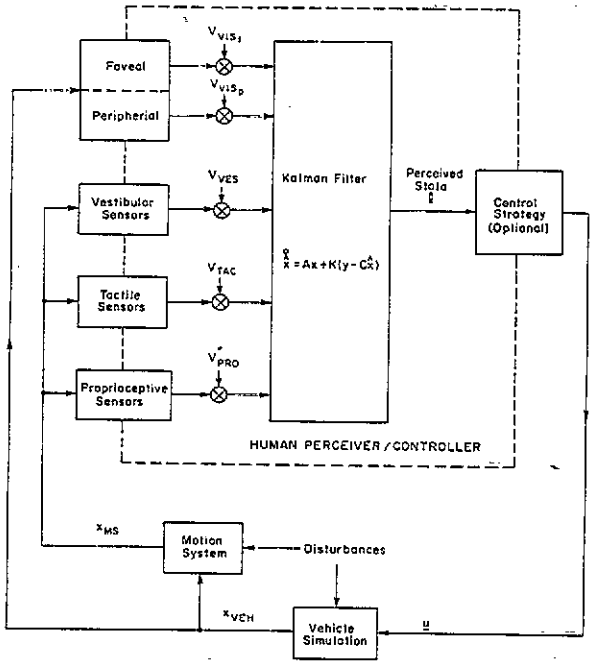

Figure 3. Block Diagram of Model for an Optimal Processor for Perception

that they may be integrated in the Kalman filter and blended with the other sensory modalities. In addition, it must, of course, be recognized that the pilot is engaged in an active flying task. Consequently, some means must be made of placing into the context of this model the pilot's expectation of aircraft response on the basis of applied demands.

It is our hope that the eventual application of pilot models based upon underlying physiological mechanisms will provide a rational way of simulator planning to provide the pilot with the minimum amount of simulator hardware required to give an adequate reproduction of orientation sensations for either training or research simulators. Furthermore, it is our goal to incorporate such a motion sensing model into the conventional simulator drive algorithm to facilitate the optimum performance of the device. Results from the modeling effort are anticipated in early 1977.

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