A RESEARCH TOOL TO IMPROVE THE EFFECTIVENESS OF PERFORMANCE MEASUREMENT WITHIN THE IOS

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ABSTRACT

Functions of the Instructor/Operator Station (IOS) include the display of information necessary for the instructor to monitor and assess student performance and to provide the student with diagnostic feedback. To support these functions, reliable, valid, and useful measures of student performance are necessary along with graphic capability to display relevant information.

The Air Combat Maneuvering Performance Measurement System (ACM PMS) is a prototype research device developed to address monitoring and debriefing requirements of the IOS. The ACM PMS includes state-of-the-art graphics display capabilities and traditional and innovative measurement algorithms to support ACM training.

The device has been interfaced with the Simulator for Air-to-Air Combat (SAAC) and the Air Combat Maneuvering Instrumentation (ACMI) range and is capable of collecting, displaying, storing, analyzing, and replaying ACM performance information gathered from training exercises conducted in both the simulator and on the range. The co-location of the SAAC and the ACMI provides a readymade environment for ACM operational training research. With the implementation of the ACM PMS, automated data collection from both simulator and airborne ACM training is possible.

The ACM PMS was designed to support a program of research intended to develop, refine, and validate useful measures of performance and to develop ways of presenting this information to both the instructor and the student. High resolution, real-time, interactive graphics are expected to yield innovative approaches to providing measures of student progress and to supplement and replace traditional methods of debriefing.

The paper describes the ACM PMS development to satisfy SAAC and ACMI user requirements, the system's capabilities, and plans to use the device for measurement validation and performance monitoring and debriefing research.

INTRODUCTION

The instructor/operator station (IOS) constitutes the interface between the instructor and the flight simulator and, in most cases, between the instructor and the student. The functionality of the IOS directly affects the quality of instruction that the student receives. Thus IOS features, specifically designed to meet instructor's needs, facilitate training. This, in turn, leads to more efficient use of the training device and other training resources.

The Air Force is conducting a program of research intended to result in future procurement of IOSs that are better designed and more cost efficient than prior systems. Warner[1] and Charles[2] have produced design guidelines that specify human factors and training functional requirements for the IOS. As military specifications, the documents will lead to the procurement of IOSs that more effectively and efficiently support simulator training.

Instructional support features which allow the instructor to control, monitor, instruct, and evaluate training exercises are expensive components of the IOS, but also facilitate simulator use as a mor effective aircrew training device (ATD). In a series of surveys (Polzella[3]; Polzella[4]; Polzella and Hubbard[5]; Polzella and Hubbard[6]) problems were identified in the specification, implementation, and use of instructional support features in a large sample of Air Force ATDs. Based on these findings and independent surveys and interviews, Easter, Kryway, Olson, Peters, Slemon and Obermeyer[7] developed the Instructor Support Feature guidelines for application to IOS design.

These studies have identified performance measurement as one of the least understood and accepted of the instructional features. In addition to taking on a great variety of implementation configurations, automated measurement algorithms have been implemented prior to the conduct of rigorous validation studies. Accurate, well understood automated performance measures must be provided to support instructors in their evaluation of student progress. Furthermore, graphic capability to display relevant performance information must be available. These IOS functions are necessary for the instructor to monitor and assess student performance and to provide the student with diagnostic feedback. It should be stressed, however, that performance measurement should support, not replace, the instructor evaluation process.

AIR COMBAT PERFORMANCE MEASUREMENT

Formally validated performance measures are not available for tactical air combat. Although some measures have been developed and have received operational aircrew acceptance, rigorous validation studies have not been carried out. Operational acceptance of a measure establishes some degree of validity for the measure. However, formal evaluation in the form of establishing the relevance, reliability, and freedom from contamination has never been demonstrated in the tactical arena.

The development and formal validation of accurate and objective measures are necessary for the evaluation of student performance and for accurate feedback. In addition, they provide measures of the effectiveness of training devices. Differences in airborne measures of student performance taken before and after simulator training can be used to quantify the effectiveness of the training device. Such measures allow training designers to adjust training syllabi to optimize the use of flight simulators and other training resources including instructors and aircraft. Used in this way, the measures facilitate the management of resources within a training program.

Air combat is perhaps the most demanding type of flying. Increased maneuverability of modern aircraft and the presence of human computer interfaces in the cockpit have increased taskload demands. The high rates and conditions of uncertainty in which motor responses, perceptual responses, and decisions must be made puts the air combat pilot at the limits of human performance.

Airborne performance has eluded study for many years, because psychologists have had to rely on aircrew debrief. Although adequate for operational debrief, verbal and written recollections cannot completely recreate the ACM event with scientific accuracy. Therefore, the collection of data on airborne behavior was the major obstacle to the psychological study of air combat and flying tasks in general.

Accurately and reliably measuring air combat performance is a goal of training psychologists. With the introduction of instrumented ranges such as the Air Combat Maneuvering Instrumentation Range/Tactical Aircrew Combat Training System (ACMI/TACTS), airborne events could be accurately recreated, stored, and graphically replayed. The ranges for the first time provided excellent

Figure 1. The ACM PMS is a graphics-based workstation and data base designed to support air combat performance measurement research.

capabilities for real-time airborne data collection. These objective data, when combined with audio replay and aircrew interview, allow psychologists to recreate the airborne events with the objectivity and precision necessary for objective studies in performance measurement development.

Flight simulators represent a useful testbed for the development and validation of air combat performance measurement. Data are typically available in flight simulators that describe relative position of opposing aircraft, pilot maneuvering of aircraft, energy management, and weapons effects. These data represent necessary ingredients of algorithms needed to describe air combat performance of proficient pilots. A research program with the specific goal of developing and validating air combat performance measures is described below.

AIR COMBAT MANEUVERING PERFORMANCE MEASUREMENT SYSTEM

Overview

As a first step in developing and validating performance measures, the Air Combat Maneuvering Performance Measurement System (ACM PMS*) was developed to collect both simulator and airborne training data. The co-location of an ACMI and the Simulator for Air-to-Air Combat (SAAC) at Luke AFB provided a readymade environment for operational air combat research. The ACM PMS has been developed as a research tool to study automated performance measurement in addition to other IOS features in support of training in air combat. The integration of the ACM PMS with the SAAC and ACMI enhances the research opportunities in this environment by providing convenient data collection from both devices. New concepts for displays and graphic replays can be tested, and performance measurement algorithms can be developed and modified.

Design and Development Process

The ACM PMS was developed through an interactive process, working with the instructors at the SAAC and at the ACMI. The layout of the displays, the performance information to be displayed and the performance measures resulted from a series of interviews and discussions with the operational training personnel. The design of the system to provide research capabilities for performance measures, displays and other features was based on the operational design.

Functional Description

The ACM PMS (Figure 1) is a graphics-based workstation and data base designed to support both research and operational training activity in an air combat simulator as well as actual airborne engagements. Data are collected during training events to provide dynamic, real-time graphics displays and graphic replay of the events at a later time. High-resolution graphics display the training engagement as it unfolds, providing both out-of-the-cockpit and rotatable three-dimensional views of the air combat engagement. In addition, real-time performance measurements of aircraft relative position and specific excess energy are computed and displayed during the training engagement. All data are available for replay for research purposes or for operational debriefing.

In addition to all information available during the training event, relative position data and specific excess energy are plotted over time during replay. These time history curves help to show the progression and relative advantages of engaging aircraft over the course of the engagement. Other playback features include arbitrary positioning to any point within the recorded engagement, with pursuant playback at slow, normal, or fast.

In addition to the graphics display capabilities, the user interface consists of an interactive, touch sensitive menu for selection of displays, data base operations, annotation of data, and flagging specific events. Flags are available to enter event-related data such as tactical radio calls that are not machine detectable. A feature is also available to standardize start and stop times of ACM engagement recordings. This feature is included to ensure the accuracy of time referenced performance measurements.

Simulator for Air-to-Air Combat (SAAC)

The SAAC is a dual cockpit air combat flight simulator with a full-field visual system. F-15 and F-16 cockpits are available at each station. The visual system is composed of eight large CRT displays covering the canopy area of each cockpit. Engagements flown in the SAAC can include up to three "aircraft." Two of the aircraft are flown from cockpits. The third is flown by the simulation computer or by an instructor using rudimentary flight controls at the IOS.

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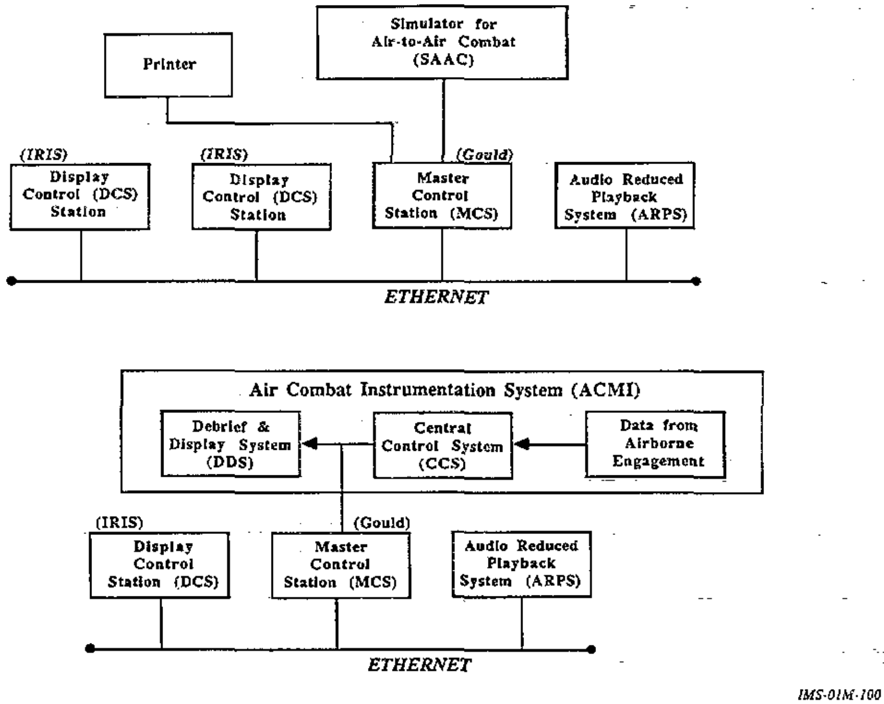

Figure 2. (a) In the upper figure, the ACM PMS configuration at the Simulator for Air-to-Air Combat is shown. (b) The ACM PMS configuration at the ACMI is shown in the lower figure.

Two ACM PMS high-resolution, graphics workstations are available at the SAAC. They are the Display Control Stations indicated in Figure 2a. One of these stations is located at the IOS and the other is placed in a debriefing area. The two stations can operate independently. Graphic replay of an engagement for debriefing or research purposes can be run on the remote station at the same time a live training engagement is being recorded and displayed by the station at the IOS. The Master Control Station is the direct interface to the SAAC. It computes the performance measures and accesses a large relational data base. The Audio Reduced Playback System provides digitized recording of all spoken communications during the training events.

Air Combat Maneuvering Instrumentation (ACMI) Range

ACMI ranges provide a realistic environment for airborne ACM training. The ACMI ranges are approximately 40 miles square. During ACM training tracking stations on the range receive information from on-board computer pods. By triangulation, the ACMI computers determine the location of the aircraft taking part in the ACM engagement. Up to 16 aircraft may be tracked, with eight aircraft considered to be a high activity level. Missile launches are simulated, and the success or failure of each shot is indicated. All computations of position, missile launch and graphics representations are performed in (near) real time and stored on tape. This information is used to graphically depict, in real time, the ACM engagement. Training officers can observe the ACM engagement as it occurs and replay it for debriefing after the training engagement.

One ACM PMS workstation is provided at the ACMI. It is the Display Control Station indicated in Figure 2b. As in the SAAC configuration, the Master Control Station is the direct interface to the ACMI. The ACMI is composed of several major subsystems, and the location of the interface to the ACM PMS is indicated. With the exception that it has one Display Control Station, all components of this configuration of the ACM PMS function exactly as they do in the SAAC configuration.

Data Configuration

The data collected by the ACM PMS are stored and used in three different file structures according to the function they are to serve. Data are initially recorded and stored in a sequentially organized file which is used to support the graphic and audio replay of air combat engagements. This data file contains all information needed to completely restructure and replay the engagement.

Data to be used for research are reduced from the replay file to a large relational data base. All data in an engagement are accessible by crossreference to all other data within an engagement. The data base includes such logical relations as aircraft and inter-aircraft position information for every aircraft pair, weapon effectiveness information, aircraft control inputs, including throttle, speed brake and stick position, information with respect to radar and lock-on procedures, and calculations of the candidate performance measures. These data are collected continuosly throughout an engagement.

The third form that the data takes is as input to statistical packages run off-line on an IBM PC/AT. Subsets of data are selected from the data base and formatted and transferred to the AT through an RS232 interface. The data are then analyzed on the IBM PC/AT using the Statistical Package for the Social Sciences (SPSS).

Candidate Performance Measures

Two candidate performance measures that have received user acceptance were included in the system design. The ACM PMS records data, computes algorithms and displays results for Energy Management and the All Aspect Maneuvering Index (AAMI).

Energy Management is based on the concept of specific excess energy. It indicates how well a pilot manages the potential and kinetic energy of the aircraft. Pruitt, Moroney and Lau[8] described the development of the energy management display and recommended a formal evaluation of the instructional effectiveness of the displayed information.

The concept of energy management has been used in the instruction of 1 v 1 basic fighter maneuvering (BFM) at the Fighter Weapons School at NAS Miramar for several years. An Energy Management Display was implemented on the Navy's TACTS range at NAS Miramar in 1977 and has been successfully used in the instruction and debrief of ACM engagements since that time. Operational acceptance, and therefore validity, of the concept has thus been demonstrated.

The AAMI represents interaircraft position and relative offensive state. It is derived from the Readiness Estimation System (Oberle and Naron[9]; McGuinness, Bouwman and Puig[10]). RES is a comprehensive system providing a Maneuver Conversion Model, a *Weapon Firing Sequence*, and a *Performance Index (PI)*. The AAMI is directly related to the PI. The AAMI is a measure of position of the fighter with respect to an adversary aircraft and with respect to weapons envelopes. An AAMI score is computed for each type of weapon the fighter has on-board. AAMI values range from zero, indicating no opportunity for a shot, to 100, indicating an optimal firing opportunity.

Energy Management and the AAMI have both been used in operational settings and receive some degree of acceptance by operational aircrews. In addition, these two measures compliment each other. During ACM the pilot is constantly evaluating trade-offs of energy state and offensive/defensive position. Before making a maneuver to increase an offensive state, the pilot must evaluate whether the aircraft has enough energy to complete the maneuver. On the other hand, before making a maneuver to increase energy state, position must be evaluated. Combining measures of energy and position therefore give a more complete picture of air combat maneuvering. Displays of these measures are continuously available both during the training engagements on the SAAC and the ACMI and during the graphic replay for debriefing and research review.

PLANNED RESEARCH

Initial research efforts will focus on modification and validation of candidate performance measures. Further efforts will provide measures to describe successful air combat performance, to evaluate pilot and training system performance, and to provide diagnostic performance feedback to the instructor and student.

The effort will begin with the development of a model of air combat performance, against which the performance measures will be evaluated. The measures will be examined for relevance to the working definition, reliability over time and changing conditions, and susceptibility to contamination. An expert systems approach may be incorporated to elicit and model air combat pilot decision-making behavior. Data analyses will identify the major factors in air combat performance. Multiple regression analyses will identify the best predictors of performance.

After performance measures are developed and validated, research will be conducted on how to optimally display this information to the instructors to assist monitoring of student performance across training exercises. Current ACM PMS graphic displays will be modified and upgraded, and changes will be systematically evaluated. Methods of displaying performance information for mission debriefing will also be investigated. Since all relevant student performance is recorded in ACM PMS, instructors will not be required to rely on memory to recreate training events. Research can focus on providing instructors with rapid access to relevant information for instructional purposes. Procedures for supplementing traditional debriefing sessions will be investigated.

Validated performance measures open the door for related research activities in air combat training. Improvements in performance as a result of training in the simulator or on the range can be empirically documented. Measures of performance enable research in such areas as the transfer of training from the simulator to airborne events and the appropriate use of the simulator for remediation of airborne flying problems.

SUMMARY

The ACM PMS is a research tool which will lead to improvements in the effectiveness of the IOS. The development of performance measurement for air combat training is expected to improve the instructor's capability to evaluate student performance. The development of effective visual displays of the performance measures will support the instructor in monitoring the student during the training event. Immediate feedback and instruction during the event would be expected to become more standardized and consistent. The display of the measurement information to the student and to the instructor during debrief will lead to improvements in the feedback that the student receives.

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