THE INTEGRATION OF VIDEODISC, CAI, AND 3D SIMULATION FOR SKILLS TRAINING

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ABSTRACT

Training in maintenance skills has become increasingly more important as the cost of replacement parts and expenditures for maintenance personnel have risen. More effective and efficient skills training has been identified as a means to limit costs through fewer false repairs, shorter down time, and decreased numbers of personnel required for maintenance. Advocates have championed various systems and devices for this training, to include in different forms: actual equipment, flat panel simulators, three-dimensional simulators, videodisc, and computer assisted instruction. This paper discusses the integration of interactive videodisc, computer generated images, and three-dimensional simulation in a total system concept for maintenance skills training. Different types of maintenance skills are identified, along with the methods and techniques for training those skills. Implementation of the methods and techniques in an integrated system is presented, to include the means for providing modeling, drill and practice, cueing and prompting, feedback, and evaluation. Two different systems are identified, rationale for the differences is provided, and the advantages each has in intended use is specified.

INTRODUCTION

The training of maintenance personnel has always been of critical importance. Training problems have become even more acute in the recent era of runaway technological advances that has resulted in increasingly complex equipment. Additionally, the costs of replacement parts and expenditures for maintenance personnel have risen. Of particular concern to those involved in maintenance training is the teaching of effective and efficient troubleshooting, as a means of limiting costs through fewer false repairs, shorter down time, and decreased numbers of maintenance personnel. In a time of decreasing training budgets that necessitate shorter maintenance training courses and increasing student/instructor ratios, it is imperative that the methods and media used for training be maximally effective.

This paper addresses the some of the difficulties associated with maintenance training. It first addresses the types of skills required of the maintenance technician. It then discusses maintenance training from the standpoint of the learning curve and talks to the media and methods that have traditionally been used to teach the trainee at each stage of learning. Finally, it discusses the use of an integrated system concept, made possible by recent technological advances. This technology has been applied to maintenance training, and this paper describes two systems that have been developed to apply the concept.

MAINTENANCE SKILLS

Equipment maintenance requires a diversity of skills, which range from simple tasks such as rotating a switch to very difficult tasks such as interpreting and following schematics in the process of tracing signal paths. Both cognitive and psychomotor behaviors are required of the maintenance technician to perform these tasks. Table 1 illustrates some of these behaviors.

CATEGORY	BEHAVIOR	OBJECT	EXAMPLE
Visual	Observation/ discrimination	Discretes	Lights
		Analog Displays	Meters
		Switch Settings	Rotaries
	Verify	Status	Lights
	Inspect	Motion	Cavaties
		Statics	Insulation
	Locate	Components	Test Set
		Test Points	Jack/Pin
Motor	Manipulate	2 Position	Pushbutton
		Multiples	Rotaries
	Adjust	Controls	Test Pot
		Screws	Null Pot
	Connect/ Disconnect	Cables	Jack/Plugs
		Leads	Test Set
	Remove/Install	Components	Amplifier
		Cables	Test Cable
	Solder/Unsolder	Wires	
Cognitive	Read	Schematics	
	Follow	Sequences	Checklist
	Know/Use	Terminology	Electronics
	Interpret	Symbology	Electronics
	Evaluate		
Auditory	Hear	Sounds	Arcing
Complex	Test (Locate, Connect, Read, Interpret, Evaluate)		
	Evaluate (Recognize normal/abnormal conditions, Select appropriate decision paths, follow sequences,...)		

TABLE 1
Sample Maintenance Behaviors, Missile Maintenance (Adapted from AMTESS Phase 1 Final Report)[1]

It is evident that there are many enabling skills and knowledges that the trainee must have before he begins to acquire the specific maintenance skills listed in the table. The enabling skills include such things as terminology, component locations, functional system knowledge, use of technical materials, and basic electronics. An effective and efficient maintenance technician must possess both of these types of skills.

MAINTENANCE TRAINING

The training of maintenance skills has been a difficult proposition. From the standpoint of a training system, the student must be taught each of the many types of maintenance skills. Each type of skill must be taught in a way that is consistent with its nature. In addition, the synergistic nature of the maintenance environment requires that the student be taught to use all of these skills as an integrated whole.

Learning Stages

The acquisition of knowledge is almost always a gradual process. As Myers[2] notes, the classical learning curve can be divided into three learning stages: acquisition, consolidation, and evaluation. In the acquisition stage, the student gains an initial familiarity with the subject matter. In the consolidation stage, he gains criterion competency. His ability to perform is tested in the evaluation phase, and administrative decisions are made on the basis of his performance.

The application of this staged process in maintenance training is clear. The student should first be guided in the acquisition of basic knowledge and skills using techniques that are appropriate for this type of learning. This is followed by practice that requires the use of these skills in a realistic manner. The cues, prompts, helps, and remediation used during this practice should gradually be reduced until the student is able to perform at a criterion level using only the materials which will be available to him on the job.

In looking at equipment maintenance holistically, it appears that the acquisition stage addresses the enabling skills and knowledge discussed above. These skills and knowledges are primarily cognitive in nature, though they are certain to include some psychomotor elements as well. These types of behavior can usually be taught using low fidelity representations such as textual descriptions, line drawings, photographs, motion pictures and other two-dimensional media.

During the evaluation stage, the student must be able to perform complex cognitive and psychomotor behaviors. The emphasis in this stage is on the student's psychomotor activities, since his cognitive processes are normally manifested in his actions. Thus, testing the student's ability requires the use of some higher fidelity three-dimensional medium, such as actual equipment or a simulator.

The consolidation stage provides a transition between the primarily cognitive acquisition stage and the primarily psychomotor evaluation stage. Although the student learns about maintenance in the acquisition stage, it is in the consolidation stage that he actually learns to do maintenance. It is here that he will gain knowledge of the synergistic aspects of the job he is to perform. The gradual fading of cues, prompts, etc., inherent in this stage, necessitates the concurrent use of both low fidelity two-dimensional media and high fidelity three-dimensional media.

Methods and Techniques

Various methods and techniques have proved to facilitate training of maintenance skills. Media selected for training must be capable of incorporating these training aids. Examples include guided practice, modeling followed by immediate application, and realistic representations of malfunctioning equipment. In addition, those proven methods and techniques common to all successful training should be available. This would include capabilities such as self-pacing, remediation, cueing and prompting, and branching.

TRADITIONAL TRAINING MEDIA

Media traditionally used for maintenance training have met the requirements of the three stages of maintenance training with varying degrees of success. Successful training has occurred when well-designed instruction has been delivered using media appropriate for the learning stage in which they have been used. Print and other two-dimensional media have been successfully employed most often when used in the acquisiton stage. Actual equipment and three-dimensional simulators have been successfully used for evaluation. Appropriate integration of the use of 2D and 3D media has resulted in some success in the consolidation stage. Unfortunately, this integration has historically been difficult to achieve.

Acquisition Stage

A wide variety of two-dimensional media have been used effectively in the acquisition stage. These media include various print materials, e.g., textbooks, programmed texts, and workbooks; photographic materials, e.g., photographs, slides, movies, and video; art work; and audio materials. Perhaps the most powerful 2D medium in existence at present is the relatively new technology which combines the use of interactive videodisc and computer graphics in a single device.

Evaluation Stage

Historically, the preferred 3D medium for the evaluation stage has been actual equipment trainers (AETs). Limitations inherent in using AETs have resulted in the growing use of simulators. These simulators have included various levels of physical and functional fidelity, ranging from low fidelity flat panel simulators to high fidelity 3D replications of actual equipment. The degree of fidelity required is a function of the tasks to be evaluated.

Consolidation Stage

The consolidation stage requires use of both 2D and 3D media. Any of the media identified above can be used effectively in this stage. But, it is apparent from the requirements for this stage, as discussed above, that all of the media used in this stage must work together as a unified whole. This requires the use of some intelligent controller to coordinate the student's interaction with all of the media employed. The use of an instructor as controller is inefficient in terms of both time and money. When administrative factors dictate a high student to instructor ratio, the training can be ineffective as well.

Recent advances in technology allow extensive use of computers in the consolidation phase. Computers are used to control 3D simulators, to control videodisc players, and to control other peripheral equipment. This allows the use of the computer as the intelligent controller in the consolidation phase. This mix of 2D, 3D, and computer as controller is likely to be the most effective means of providing training in this consolidation stage.

INTEGRATED SYSTEM CONCEPT

The above discussion indicates the need for a system which integrates the use of both 2D and 3D media. Such a system could be effectively used in all three learning stages. The 2D portion used alone could be used for acquisition applications, while the use of the 3D by itself would suffice for evaluation. In addition, the integration of the use of the two in various proportions would make it a potent, cost- and training-effective instrument in the crucial consolidation stage.

Until recently, technology has not been available which would allow the integration of 2D and 3D media into a unified system. Recent breakthroughs have allowed the Grumman Aerospace Corporation to design and construct two such systems, and they are currently under operational evaluation.

AMTESS

The Army Maintenance Training and Evaluation Simulation System (AMTESS) is a generic maintenance training system developed for the U.S. Army, Project Manager for Training Devices. The version of AMTESS developed by Grumman [1 3] consists of two modules: a student station and a 3D simulator (See Figure 1). These two modules can be used as independent elements, or they can work together as an integrated system.

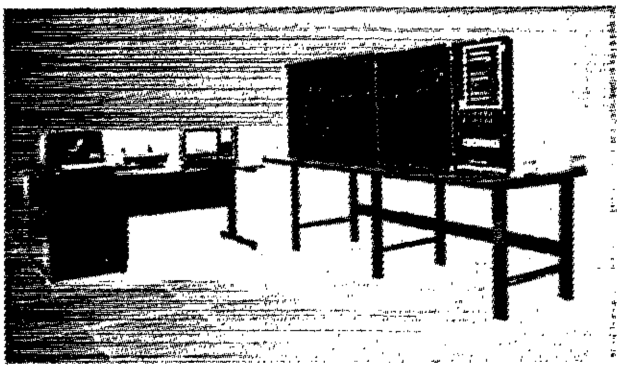

Figure 1 Integrated AMTESS Modules

3D Module. 3D simulator modules can be either system or training program specific. Math models cause each module to react as the real equipment it simulates would under both normal and degraded conditions. These models make no judgment as to the correctness of student actions. The 3D simulator provides the technician with the opportunity to manipulate controls, observe indicators, and troubleshoot malfunctions on equipment that is physically and functionally representative of the actual equipment. Computer control of the 3D via a microprocessor provides all of the normal and abnormal indications of all components, controls, and indicators.

Two different prototype 3D modules have been delivered and currently are under evaluation. An automotive module designed to train generating and starting system troubleshooting on the M110A2 self-propelled howitzer is at Aberdeen Proving Ground, Maryland (See Figure 2), and a missile module designed to train troubleshooting on the transmitter of the High Power Illuminator Radar of the HAWK Missile System is at Fort Bliss, Texas. (See Figure 3).

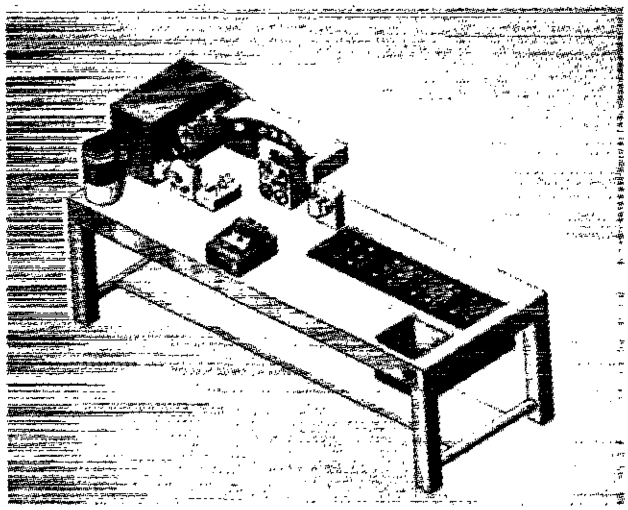

Figure 2 AMTESS Automotive 3D

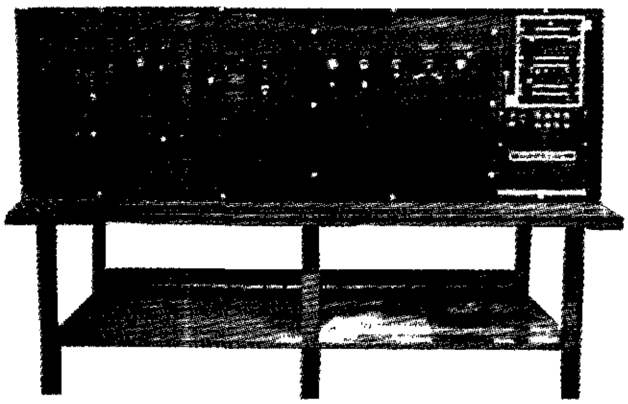

Figure 3 AMTESS Missile 3D

2D Module. The 2D module can be used in a stand-alone mode, or it can be connected to any 3D module for tandem operation (See Figure 4). Two-way communication between the student and the 2D is accomplished using a color television monitor, which can display videodisc and/or computer generated images. Student 2D responses are registered through a touch bezel attached to the TV monitor. The videodisc player, TV monitor, and touch bezel are all under the control of a single microprocessor with dual drive floppy disk. When operating in tandem, the 2D processor also controls the 3D simulator.

Figure 4 AMTESS Student Station

The 2D can be used for various types of instructional activities, e.g., presentations, tutorials, or drill and practice. Various instructional techniques can be used to facilitate student learning. For example, modeling of expert behavior on the 2D can be followed by immediate student immitation of the modeled behavior on the 3D. The 2D can monitor student actions on a continuous basis. It can branch to provide specific guidance, remediation, and/or feedback as appropriate.

TJS

The Tactical Jamming Sustem (TJS) trainer for the U.S. Navy's EA-6B aircraft was developed for the Naval Air Systems Command, and has been delivered to the U.S. Naval Air Station, Whidbey Island.[4] While configured somewhat differently than AMTESS, the TJS contains the same elements, i.e., videodisc, computer generated graphics, student response touch bezel, computer control, and 3D simulation. (See Figure 5). The TJS trainer is weapon system specific, and although it could be modified for other applications, e.g., the training of operator procedures, it was developed to address TJS maintenance training requirements.

SYSTEM TRAINING CAPABILITIES

Integrated System Trainers (ISTs) are an answer to the requirement for concurrent use of 2D and 3D media in the consolidation stage. Having both 2D and 3D capabilities, they also have full capability for use in the acquisition and evaluation stages. The ability to deliver that training using a variety of methods and

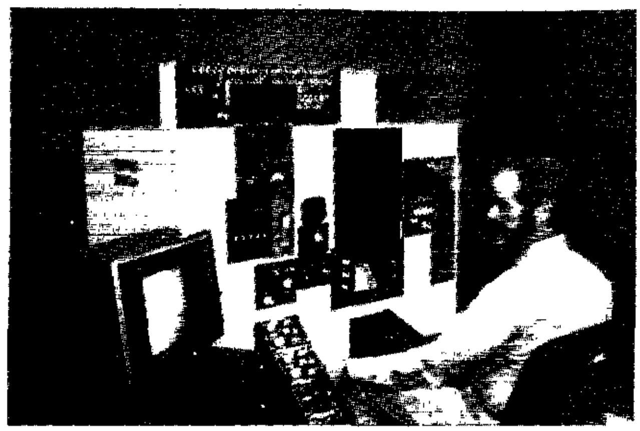

Figure 5 TJS Maintenance Trainer

techniques has been demonstrated in the lessons developed for the AMTESS and TJS systems. The following paragraphs describe the ways in which various features of the ISTs have been used.

The heart of an IST is the computer in the 2D, which controls the student's interaction with all elements of both the 2D and 3D modules. It monitors his progress and provides cues, prompts, instruction, knowledge of results, and help to the student in accordance to developed lesson materials. The student interacts with the 2D using the touch bezel attached to the video screen, and his manipulations of the various components on the module are reported to the 2D computer using the communication lines between the modules.

On the 2D module, videodisc images have been used to store instructional materials in the form of textual, graphic, pictorial, and auditory information. The random access capability of the player allows the computer to call up either single frame or motion sequences in an order that is appropriate for instructional requirements. The motion capability can be used to present audio, visual, or audiovisual sequences. Two audio channels on the disc permit additional flexibility of use.

Computer generated graphics extend the capability of the videodisc, and provide a quick and easy way to update lessons. The generation of these computer presentations is under 2D computer control, so the messages can be tailored to individual circumstances. Communication between the 2D and 3D computers allows the system to call up video and computer graphic images in response to student actions.

Use of the 2D computer as the executive permits the two parts of the sytem to be used in any desired proportion. This flexibility allows lesson materials to be tailored to the specific requirements of each learning stage.

This not only increases instructor reliability, and consistency of training, it permits the instructor to use time more efficiently. This allows the instructor to become more of a resource manager, using all of his available tools, and additionally frees the instructor to spend time with those students who would best benefit from that direct interface.

During the acquisition stage, videodisc images and computer graphics have been used extensively to provide cues, prompts, and remediation, and for student requested help sequences. Various levels of help have been made available, with alternate paths based on student performance. Relatively speaking, very little use of the 3D module has been made during this stage.

During the consolidation phase, the student is weaned from dependence on the 2D. Fairly heavy use is made of the student station early in this stage, as it guides his interactions with the 3D. By the end of this stage, however, the student interacts almost exclusively with the 3D and interacts with the 2D only when he specifically asks for help.

In the evaluation stage, the 2D continues to monitor individual actions to maintain records of student performance. The interaction monitored will be almost entirely with the 3D, and virtually no video or computer generated messages will be used.

THE FUTURE OF SKILLS TRAINING

ISTs are currently being evaluated for training effectiveness and transfer of learning. Their potential for providing effective training in all three learning stages will be realized as lessons are developed which use the diversity of methods and techniques available, and are applied across a wide range of training programs.

New applications are in progress. Technology for training devices is constantly improving. Microprocessor technology continues to grow. The new generation of videodisc development will likely include single frame audio and programmable videodiscs. Integrated Systems Trainers are the future of skills training.

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James R. Stonge is an Instructional Systems Engineer at Grumman Aerospace Corporation. He was the Instructional Systems Development (ISD) manager on the Grumman AMTESS program, with responsibility for all ISD activities on that project. In addition, he developed all of the Missile Maintenance Training associated with AMTESS. Previous duties at Grumman include ISD activities associated with the A6-E Maintenance Trainer for the Detecting and Ranging Set (DRS). Prior to joining Grumman, he was on the faculty of the Department of Instructional Systems Technology Indiana University. He held various positions while serving 11 years in the US Air Force, including that of Instructor Missile Combat Crew Commander and Training Squadron Commander. Mr. Stonge holds an AB in Education, Lycoming College; MBA, University of Missouri; MS in Education, Southern Illinois University - Edwardsville; and has completed all doctoral work except completing dissertation (ABD), Indiana University.