ARTIFICIAL INTELLIGENCE/EXPERT SYSTEM (M-16A1 RIFLE)

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ABSTRACT

A program of research to develop an Artificial Intelligence (AI) Research Test Bed has been jointly initiated by the Army Project Manager for Training Devices, the Army Human Engineering Laboratory, and the Naval Training Equipment Center's Research Department. The objectives of the program are twofold. First, it is desired to explore how to design intelligent computer assisted instruction systems to perform teaching roles now performed by humans. Second, through systematic experimental studies, it is desired to acquire the basic knowledge needed to design cost efficient training systems for future line-of-sight direct fire weapon systems. Presently, the test bed's design includes an experimental M-16A1 rifle marksmanship prototype training device and an AI training computer. The training device comprises a terrain model board; a demilitarized M-16A1 rifle instrumented to measure the shooter's aiming point, sight adjustment, and trigger control; a physiological measurement subsystem; and a microcomputer system. The training computer will be a LISP machine interfaced to the simulation microcomputer. An expert system will reside on the training computer to provide surrogate instructor functionality for the test. This paper describes the test bed with emphasis on those components nearing completion and soon to be made available for experimental use. The physiological measurement subsystem and AI training computer are currently in the design phase, and are described in functional terms only.

INTRODUCTION

A program of research to develop an Artificial Intelligence (AI) Research Test Bed has been jointly initiated by the Army Project Manager for Training Devices (PM TRADE), the Army Human Engineering Laboratory (HEL), and the Naval Training Equipment Center's (NAVTRAEQUIPCEN) Research Department. The objectives of this program are twofold. First, it is desired to explore how to design intelligent computer assisted instruction (ICAI) systems to perform teaching roles now performed by humans. Second, through systematic experimental studies it is desired to acquire the basic knowledge needed to design cost efficient training systems for future line-of-sight direct fire weapon systems. The M-16A1 rifle has been selected to be the first direct fire weapon system to be studied within the context of the test bed. This selection was made for two reasons. First, successful test bed developments for the rifle will be beneficial to all Army combat arms. This is because the operation of many future individual weapons involves the use of M16-like marksmanship skills. Second, because the underlying principles of basic rifle marksmanship are well understood, it was determined that the test bed could be configured for the marksmanship task with a minimum expenditure of dollar and time resources.

Presently, the test bed's design includes an experimental M-16A1 rifle marksmanship prototype training device and an AI training computer. The training device comprises a terrain model board with static and moving pop-up targets located at a variety of scaled ranges; a demilitarized M-16A1 rifle instrumented to measure the shooter's aiming point, sight adjustment, and trigger control; a physiological measurement subsystem to monitor selected physiological activities such as heart action and respiration; and a microcomputer system to control the simulation. Current plans call for development of the training device component, less physiological measurement subsystem, to be completed by the end of Fiscal Year 1984. Physiological measurement subsystem development will be completed during Fiscal Year 1985. An overall system photograph is at Figure 1.

The training computer will be a LISP machine interfaced to the simulation microcomputer, which is part of the prototype training device. An expert system will reside on the training computer. The expert system will provide surrogate instructor functionality for the test bed through an architecture based on expert systems modeling and ICAI techniques. Expert system components will include student, expert marksman, and instructor models, which collectively form the basis for presentation of marksman knowledge, demonstration of correct behavior, student performance appraisal, and student performance feedback. The training computer and the marksmanship expert system are not expected to be available for test bed integration until the beginning of Fiscal Year 1986.

The remainder of this paper describes that portion of the test bed comprising the prototype training device.

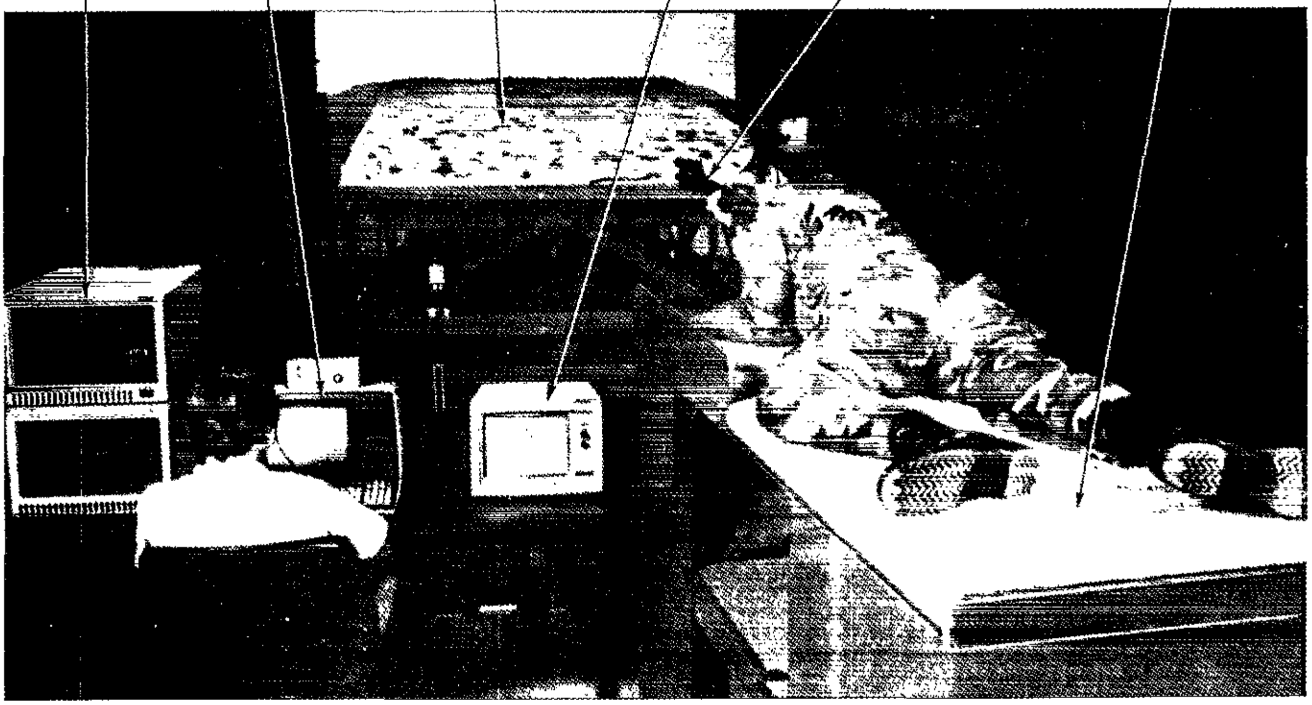

Figure 1. Overall System.

DESCRIPTION OF THE PROTOTYPE TRAINING DEVICE

The prototype training device is an electro-optic based, multiprocessor controlled, model board based, real time experimental system consisting of the following subsystems:

- o Terrain and Target Model Board
- o Instrumented M-16A1 Rifle
- o Simulation System Microcomputer

Subsequent paragraphs present a detailed description of each subsystem.

Terrain and Target Model Board

The terrain board is 8 feet wide and 17 feet long. The shooter views the terrain board from a station located 20 feet from the front edge of the board. The targets are E and F man-shaped silhouettes scaled to simulate ranges varying from 50 to 500 meters. Terrain features also use a variable scale. Ten stationary (pop-up) targets and four movable targets capable of both lateral and up-down motion are presented on a terrain board. Moving targets move along a four foot track perpendicular to the shooter's line-of-sight. Acceleration and velocity components of the moving targets are microprocessor controlled using stepper motors. Each target has mounted on its back an invisible infrared (IR) light source (an infrared emitting diode (IRED)). The IRED has a maximum power output of 12 milliwatts and emits at a peak wavelength of 880 nm. The IR light source, emitted through a 1/16 diameter aperture, is detected by the Charged Coupled Device (CCD) camera on the rifle and translated into shooter aiming error. This function will be addressed as part of the rifle subsystem. A terrain board photograph with several visible targets is shown at Figure 2.

Figure 2. Terrain and Target Model Board.

Instrumented M-16A1 Rifle

An M-16A1 assault rifle has been demilitarized, modified and instrumented to permit measurement of many of its features and functions. Outwardly, with the exception of modified features, it has the appearance of an operational M-16A1 rifle. The instrumented features include:

- Aiming error
- Accurate trigger travel and adjustable squeeze pressure
- Magazine insertion/extraction and monitoring of rounds remaining
- Automatic/semi-automatic mode selection
- Adjustable sights
- Operable charging handle
- Muzzle climb to simulate recoil effects

Attached to the rifle muzzle is a Charge Coupled Device (CCD) camera boresighted to the front sight. Figure 3 presents two views of the mounted CCD. The camera is approximately boresighted mechanically and then electronically positioned precisely by the computer. As the CCD camera views the IR light source at the target, data is generated to determine aiming error in azimuth and elevation. Error data are combined with range data and gravity drop to determine "bullet" strike. Effects of variable wind and "bullet" dispersion can also be selected. If the target is moving, lead is incorporated in the "bullet" strike computation. Lead is a function of both the range and the velocity of the moving target. Velocity of the target is determined from the step count divided by the fundamental period of the system (48 msec). The strike of the "bullet" as well as aiming point prior to and after firing, are displayed on a monitor in close proximity to the shooter.

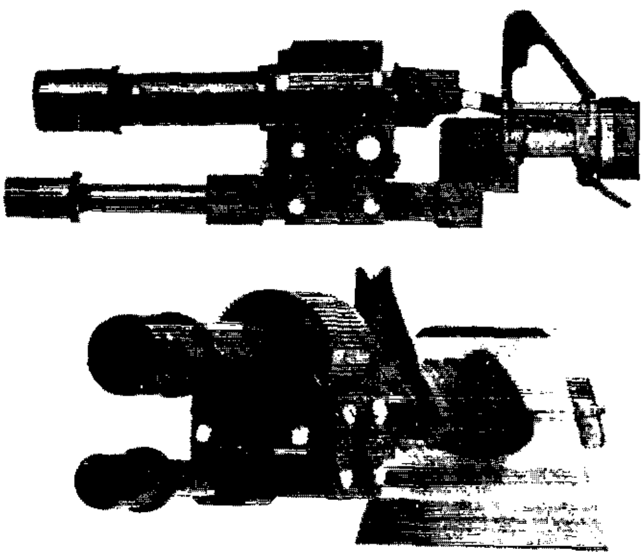

Figure 3. Mounted CCD Camera.

Trigger travel and adjustable squeeze pressure is provided for firing realism. Mounted with the trigger mechanism is a linear travel potentiometer which produces a varying voltage as the trigger moves. This voltage is monitored to track trigger position. A magazine insertion/extraction feature is provided for realism and monitored to prevent weapon fire with no magazine inserted. Each magazine contains a capacitor which when charged produces a current pulse when the magazine is inserted into the rifle. This "pulse" indicates a fresh magazine has been inserted. Once the capacitor has discharged, it must be recharged before the magazine is reinserted into the rifle. If it is not recharged, the magazine will register empty upon reinsertion. Rounds remaining is monitored to limit firing to the number of rounds held by a magazine. Automatic/semi-automatic firing mode selection is provided for realism and flexibility in firing scenarios, and monitored as part of the computer circuitry that tracks rounds fired and rounds remaining. Adjustable front and rear sights used for weapon zeroing, and for realism, are monitored as an element of the shooter diagnostic process. Both automatic/semiautomatic selection and front sight selection are determined from switches mounted on the rifle. An operating charge handle provides a means to chamber a simulated round and is interactive with the magazine features previously addressed.

Rifle recoil simulation, provided for realism, is accomplished with a high pressure air blast ejected from the tip of the barrel in a downward direction. Impulse direction is adjustable to provide up-and-to-the-left or up-and-to-the-right muzzle climb. The overall effect of the air impulse is to raise the rifle barrel, thereby disturbing the aim point and forcing the shooter to re-aim between shots. The amount of muzzle climb is controlled by raising or lowering the air pressure to the rifle.

Simulation System Microcomputer

The diverse processes incorporated into the test bed design necessitated selection of a computer having a large auxillary mass storage and a real time multi-tasking capability. Moreover, it had to be interfaceable with either a VAX or personalized LISP system and expandable to accommodate changing system requirements. The Intel 86/380 system meets all these requirements and in addition, the experience gained from previous application of Intel hardware and software developments was available. Figure 4 presents on overall system block diagram to which succeeding Intel 86/380 comments are keyed.

System Controller - The system controller 86/30 board stores and retrieves data from the disks; loads the proper scenarios into the controllers on the Stepper Motor Controller boards; performs ballistic calculations; and at start up, displays menus which allow the test operator to select such variables as the type of target, range, speed of moving targets, percent of target exposed. Other menus allow for the selection of wind speed and direction, recoil, sound

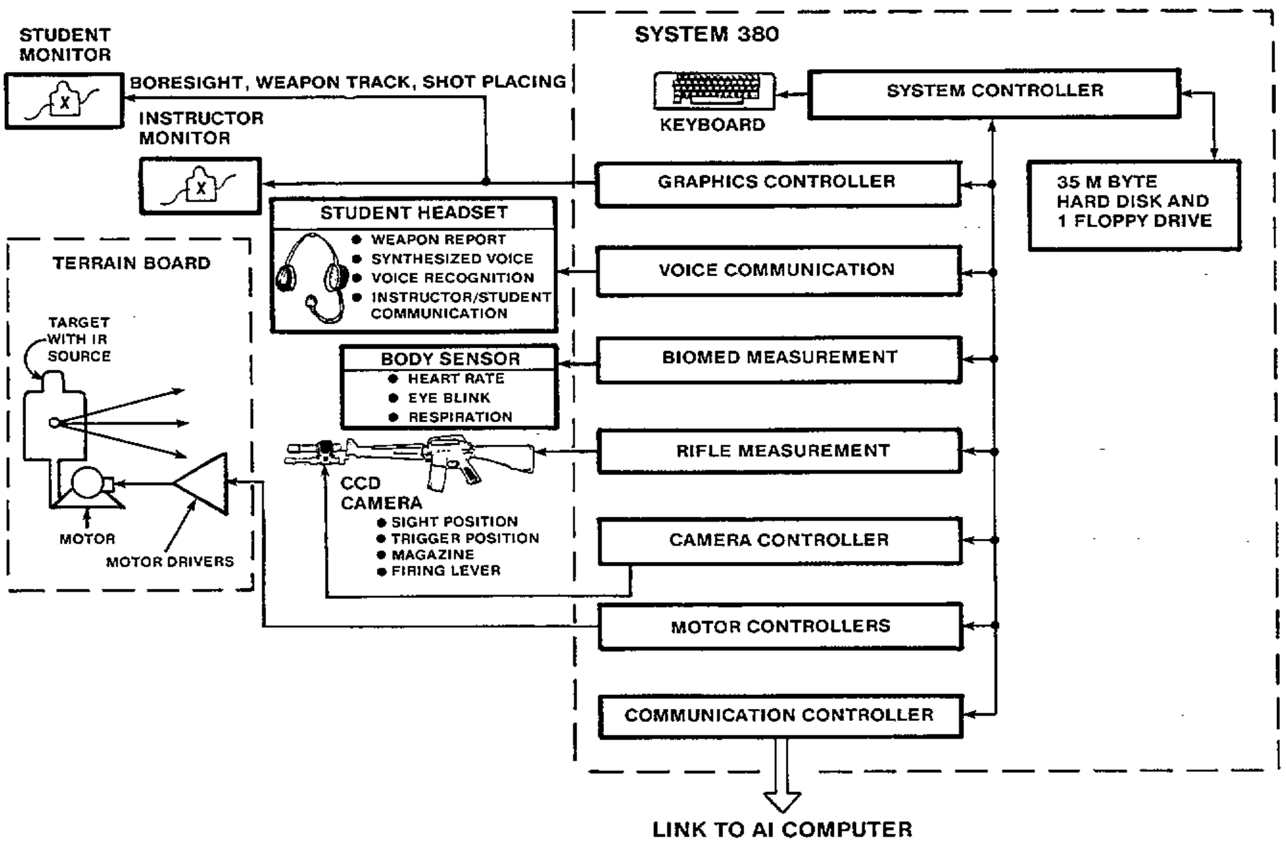

Figure 4. Overall System Block Diagram.

effects, target action upon being hit, and the ballistic characteristics of the rifle/ammunition combination. These start up menus allow the test operator to configure the type scenario desired using only one or two key-strokes to select menu items.

Graphics/Camera Controller - An 86/14 Graphics Controller (GC) board controls the CCD camera system and two Matrox boards; one video frame grabber and one for graphics generation. Additionally, the GC board draws the graphics presented on the student and instructor monitors.

A pictorial representation of aiming information, "bullet" strike and other data is provided using an Intel Video Graphics Controller (VGC) board. The VGC is installed on and interfaces with an 86/14 "host" micro-computer board. Communication between the VGC and host computer is supported by software in the host computer.

The main components of the VGC board are a graphics display controller microcircuit and 32 Kbytes of random access display memory. The VGC board has the capability of reading and writing to the display memory using one of several pre-programmed algorithms allowing special shapes to be very quickly drawn.

Horizontal and vertical sync information for a color raster are provided by the VGC after initialization. The raster consists of an array of 216 rows and 288 columns of dots or pixels. Each pixel has a corresponding base address in VGC memory and can be set to any one of eight colors (black, red, blue, magenta, green, yellow, cyan, or white) by altering the contents of its memory location. Lines, arcs and rectangles can be drawn by using special commands that activate preprogrammed algorithms on the VGC. By drawing arcs, lines and rectangles, the targets can be drawn on the display screen.

When the system is in operation, trajectory calculations are used to describe the location of the "bullet" strike on the target. This location is converted to X-Y coordinates, passed to the host computer, and in turn to the VGC. "Bullet" strike position is then displayed on the graphics monitor as a spot on a target picture thus providing an instantaneous indication of where the shooter "hit" the target. Shooter tracking can be shown in a similar manner. Data representative of the aiming point are taken for a period of time before the shot is fired and can be displayed relative to the target on the graphics color monitor. Figure 5 is a picture of the data console and graphics monitor.

Voice Communication - Two way voice communication between the test bed and the user are mediated by a speech recognition/speech synthesis system. Human speech is recognized by an Intel Speech Transaction Board (iSBC 576). This is normally a speaker dependent system. However, in the test bed environment, the system

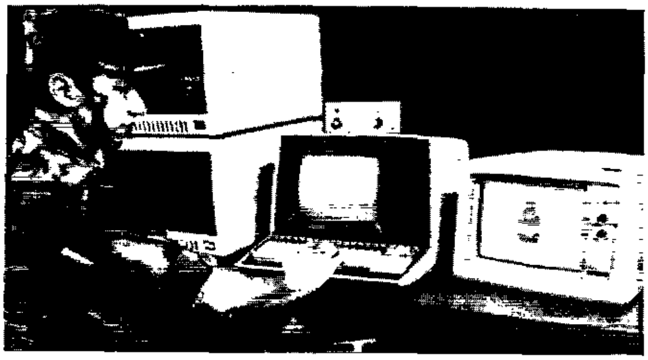

Figure 5. Data Console and Graphics Monitor.

has been trained to respond in a speaker independent way to the words "yes" and "no." The speech recognition system operates in two modes; vocabulary recognition and speech transaction processing. In the vocabulary recognition mode, a "dictionary" of words, and the voice patterns corresponding to them, are loaded into memory. When a voice command is spoken into the microphone, the board reports the three closest matches to the controlling processor along with the level of confidence, expressed as a percentage, that the word is a match. If a match occurs the appropriate action is initiated by the test bed.

In the second mode, a speech transaction program is loaded into memory on the Speech Transaction Board which inturn executes the program taking appropriate actions based upon verbal inputs.

As part of a transaction, the speech recognition board can send data to a Prose 2000 text-to-speech converter either by way of the controlling processor or directly by a separate serial channel. The text-to-speech converter will allow the AI Computer to change commands easily because the Prose 2000 accepts standard ASCII text and converts it into speech. This allows an almost unlimited vocabulary. The controlling processor can change a number of the parameters of the Prose 2000 "on the fly" by inserting escape sequences into the text. Among these are: voice pitch, the speed at which words are spoken, and speech signal attenuation (volume control). The Prose 2000 can also generate tones of various frequencies.

Rifle Measurement - The Intel Analog Interface Board, iSBC 88/40, is a single board measurement and control computer with onboard microcircuits for peripheral control, communications, and timer functions capable of performing analog to digital conversion. The 88/40 board reads sensors on the rifle and shooter, and controls the simulated recoil and rifle shot sound effects. The computer residing on the 88/40 board functions as an I/O interface between the M-16A1 test rifle and other test bed components.

Logic levels from switches mounted in the test rifle are sampled and stored by connecting outputs from the rifle to the peripheral interface on the 88/40. Analog signals such as trigger position from the rifle and the shooter are connected to the inputs of the analog to digital converter. Two additional lines are also brought into the 88/40 that provide interrupts signifying the exact time the trigger is pulled and when a new magazine is inserted.

Rifle switches and potentiometers indicating the status of such things as trigger position, sight status, and magazine status, are monitored continuously until the trigger snaps. The trigger snap generates an interrupt to the computer. Control signals are generated to provide a "bang" to the shooter head set along with recoil.

When a new magazine is inserted in the rifle, an interrupt is generated that will initialize the magazine cartridge count to 30 (31 if a cartridge was already chambered).

Motor Controller - Targets are under the control of the host computer via two custom fabricated boards. There are 10 stationary pop-up targets and 4 movable targets. All pop-ups use a single stepper motor in a gear and post mechanism. Movable targets require two steppers, the gear and post mechanism for up and down motion and a higher power stepper for lateral motion. In all, there are 18 stepper motors receiving commands from the two stepper motor controller (SMC) boards. One board is dedicated to commanding the pop-ups while the second board commands the movable targets. These boards are interchangeable and capable of commanding 10 independent stepper motors.

Each motor is controlled by a Cybernetics Microsystems CY512. High level commands in the form of ASCII characters are sent to the CY512 from the System Controller via a Universal Peripheral Interface (UPI). The CY512 then acts as a stand alone device controlling a stepper motor in accordance with the instructions mentioned above.

A pair of Intel UPI chips are resident on each SMC board. These devices provide the link between the CY512 controllers and the System Controller. Each UPI is programmed to route "Scenarios" to the CY512 selected by the System Controller. "Scenarios" consist of a string of ASCII characters which command the CY512 to move the target. One UPI is programmed to keep a count of the absolute position of each motor. For each step completed, the CY512 outputs an active low pulse which is monitored by UPI-C. UPI-C maintains position by incrementing (positive direction) or decrementing (negative direction) a counter. The internal RAM of UPI-C is set up with 10 counters. The host computer can interrupt UPI-C at anytime to receive a count or "position" of the motor selected.

SUMMARY

At present, the prototype training device is being validated. Validation data will compare rifle marksmanship performance of 30 soldier subjects and 15 ROTC subjects on the test bed with live fire marksmanship performance on a field range at Fort Benning, Georgia. Both stationary and moving targets are being utilized. Data are also being collected at the same time to formulate the production rules for the AI program. Data on early test results will be presented at the 6th Interservice/Industry Training Equipment Conference in October 1984. Validation results are scheduled to become available in December 1984, at which time the prototype training device will undergo retrofit if necessary, and then be made available for experimental use.

ABOUT THE AUTHORS

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