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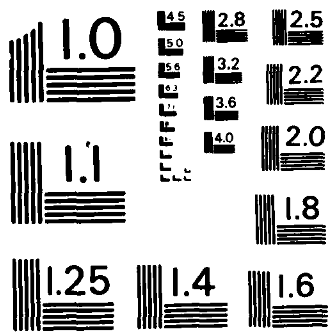

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Research Report ONR-85-5

DEVELOPMENT OF A MICROCOMPUTER-BASED ADAPTIVE TESTING SYSTEM

PHASE II -- IMPLEMENTATION

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December 1985

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The goal of this project was to develop an inexpensive, self-contained system of hardware and software to support the development, administration, and evaluation of computerized adaptive tests. Toward that goal, commercial hardware was selected and a comprehensive software system called the MicroCAT[tm] Testing System was developed. The MicroCAT system was implemented in a local area network configuration at the Basic Electricity and Electronics School of the Naval Training Center in San Diego. It was integrated into the school's computer-managed instruction system and made available to the University of Illinois for research on adaptive diagnostic testing. In response to suggestions from users at this and other non-government implementations, the MicroCAT system was refined into a marketable commercial product.

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ABSTRACT

The goal of this project was to develop an inexpensive, self-contained system of hardware and software to support the development, administration, and evaluation of computerized adaptive tests. Toward that goal, commercial hardware was selected and a comprehensive software system called the MicroCAT^{tm} Testing System was developed. The MicroCAT system was implemented in a local area network configuration at the Basic Electricity and Electronics School of the Naval Training Center in San Diego. It was integrated into the school's computer-managed instruction system and made available to the University of Illinois for research on adaptive diagnostic testing. In response to suggestions from users at this and other non-government implementations, the MicroCAT system was refined into a marketable commercial product.

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INTRODUCTION

Computerized adaptive testing offers a number of advantages over conventional testing including security, efficiency, and immediacy of results. However, adaptive tests must be administered on a computer, which can mean large expenditures for equipment and system development. The overall objective of this project was to ameliorate this problem by developing an inexpensive, self-contained system of hardware and software for the administration of a wide variety of tests.

The effort consisted of two contractually separate phases. During Phase I, a system was designed to facilitate the development and to support the administration of adaptive and conventional computerized tests. The system contained extensive facilities for entering test items, organizing them into adaptive and conventional tests, administering the tests, and analyzing the results. The design was documented by a preliminary user's manual.

Phase II of the effort had four objectives: 1) to select and procure computer hardware for implementing the system, 2) to implement on the selected hardware the software system described in the preliminary user's manual, 3) to install and field test the equipment at evaluation sites, and 4) to evaluate and refine the system based on feedback from the test sites. Progress toward each of these objectives is described below.

SELECTION OF THE HARDWARE

It was originally anticipated that the selection of the hardware would proceed in two stages. First, a list would be compiled including all of the computer hardware that could adequately administer psychological tests. In the second stage, three systems would be selected from the list and tested extensively. The evaluation was to have considered processing power, clarity of display, system reliability, and system durability.

By the time the Phase II contract was awarded, however, the microcomputer hardware environment had changed considerably. Many systems on the market could meet the minimum requirements for psychological testing. Processing power, display quality, and durability were no longer issues (although system reliability was still important). Two major new criteria had appeared, however: adherence to new industry standards, and manufacturer longevity. IBM had announced its personal computer some months previously, and it had become the de facto industry standard. Many small manufacturers of quality equipment had gone out of business, in part because of their lack of compatibility with IBM products.

It appeared to be a poor investment of time and equipment to extensively evaluate the performance capabilities of three different microcomputers when it was apparent that factors other than performance would determine the selection. Therefore, the selection was made on the basis of specification research. Seven factors were considered in selecting the hardware: computing power, mass storage capacity, graphics capability, networking capability, manufacturer prominence, separation of disks from the display, and manufacturing site.

Computing power is essential in an adaptive testing system because a substantial amount of arithmetic computation must be performed for computing scores as well as for selecting items. Experience had shown that the Intel 8088 microprocessor, running at a clock speed of approximately 5 MHz, was capable of performing all adaptive testing functions in a single-user testing environment. Since this chip had become something of a standard in the microcomputer industry, acceptable computing power was loosely defined as power greater than or equal to that of the 8088.

Systems analysis in Phase I of this effort had suggested that mass storage approaching one megabyte would be required for adaptive testing. A number of computer manufacturers had adopted diskette drives capable of storing 320 to 360 kb. Although it was somewhat short of the one-megabyte requirement, a combination of two diskettes with a minimum of 320 kb each was established as the minimum standard.

Pixel graphics were required to represent drawings such as might be encountered in a test like the Armed Services Vocational Aptitude Battery (ASVAB). In general, the higher the resolution, the better the picture. A minimum standard of graphics resolution was set at 300 pixels horizontally and 200 pixels vertically.

The intended field test application was to require a network capable of supporting a minimum of 24 testing stations. The items would be kept on a hard disk at one of the stations and would have to be transmitted to each testing station, one at a time, upon demand. The minimum acceptable network was established as one that could support this many stations and transmit data fast enough that the worst case would not cause the system to slow down appreciably. Some simple arithmetic yielded a minimum acceptable network speed. Considering a worst case in which all stations would request items simultaneously, each item would contain one kilobyte of information, and the worst response time would be one second, the network bus speed had to be at least 0.192 megabits per second.

The preceding four factors were considered qualifier factors; a system had to be acceptable on all four to be considered. The remaining three were used to rank the acceptable candidates.

Prominence referred to the size of the manufacturer, the length of time the manufacturer had been making microcomputers or similar equipment, the number of microcomputers the manufacturer had delivered, and the perceived probability that the manufacturer would continue to make microcomputer equipment. This factor was considered important because it is difficult to obtain maintenance support for equipment that is no longer being manufactured or that was developed by a company that is no longer in business.

The ability to separate the diskette drives from the display and response device was considered important because there was some concern that examinees might put things into the diskette drives if they were openly visible and accessible. This would be especially important in a hostile environment that might surround the administration of some psychological tests.

The final factor, manufacturing site, was important because of government procurement regulations that might require some potential users to buy American-made equipment.

Four microcomputers were considered acceptable on all four qualifier factors. These were the IBM PC, the Texas Instruments Professional Computer, the Xerox 16/8, and the WICAT S-150. Of these, the IBM PC was ranked the highest. It differed from its two closest competitors (the Texas Instruments Professional and the Xerox 16/8) only in the prominence of the company as a manufacturer of computer equipment.

A final configuration was designed around the IBM PC and consisted of a network of testing stations communicating with two network servers. The connecting network selected was the 3COM Ethernet network. This network was selected because it was the only commercially available network that met the specifications and could be serviced on a national basis along with the computer equipment. The testing stations were configured as single-diskette computers. The servers were IBM PC-XT computers, each having a hard disk and a diskette drive.

Bids were then solicited from all vendors who could supply and maintain the equipment as required. Maintenance was a difficult requirement because, although the equipment was being purchased in Minnesota, all that was known at the time about its ultimate location was that it would not be Minnesota. Therefore, the vendor had to have a national maintenance network in place. Only two companies were able to respond at the time the bid was requested: Computerland and Sears. (IBM could not respond because the 3COM network was not an IBM product.) Computerland won the bid on the basis of its lower price.

Four computers were purchased immediately and assembled into a small version of the future testing network. The remaining computers were purchased later in the project when they were needed.

IMPLEMENTATION OF THE SOFTWARE

Although the basic design of the software was completed during Phase I of the effort and much of the software had been written at private expense between the project's two phases, substantial design and augmentation were required for the final system. The field test application was selected early in the project: the system would be used at the Basic Electricity and Electronics (BE&E) School at the Naval Training Center (NTC) in San Diego. It would be used to implement new forms of diagnostic testing being developed at the University of Illinois.

Meetings with Navy and University of Illinois personnel early in this phase of the project revealed two deficiencies in the system. First, it had no graphics capabilities. Graphics would be necessary to display the electronics items that would be administered in the BE&E School. The second deficiency was that the system could not specify tests using the new diagnostic algorithms that were being developed. To solve this problem, it was agreed that a custom interface would be added to the system so that procedures to implement these new techniques could be developed in FORTRAN or Pascal.

The majority of the design specified in Phase I had been implemented on a PDP 11 minicomputer. Software development for Phase II began by transferring these programs to the IBM personal computers and modifying them as necessary. In general, this was not a difficult task. The major changes were in version-specific Pascal differences and operating-system-specific function calls.

An initial version of a graphics editor was designed and developed. Several preliminary versions were delivered to the University of Illinois for evaluation. The final version allowed colored drawings to be developed interactively on the IBM PC using either a mouse or the arrow keys for cursor movement.

The design of the test development software provided for an authoring language to develop the tests and a compiler to translate the authoring language into a form that could be executed quickly. In the version developed for the IBM PC, the compiler also bit-maps and compresses the graphics items. While it might take as much as a minute for the computer to display an item using the graphics commands, the compressed bit-mapped version can be displayed in less than half a second.

The entire software system developed was described in the final *User's Manual for the MicroCAT Testing System*, distributed as Research Report ONR-85-1 (Assessment Systems Corporation, 1984). This manual contains an overview of computerized adaptive testing and discusses the many features of the MicroCAT^{tm} Testing System in four sections corresponding to the four MicroCAT subsystems.

The section on the Development Subsystem describes the Graphics Item Banker, the font generator, creating tests from predefined test templates, and the test compiler. The section on the Examination Subsystem describes how to administer tests. The Assessment Subsystem section describes programs for collecting data from several administrations into a common file, performing conventional item analyses, estimating item response theory (IRT) item parameters, evaluating the adaptive potential of an item pool, and computing test validity coefficients. Finally, the section on the Management Subsystem describes programs that allow a network of testing stations to be managed from a single proctoring terminal.

The User's Manual also describes the practical details of the authoring language, MCATL (Minnesota Computerized Adaptive Testing Language). Further details about this authoring language are provided in Research Report

ONR-85-3, *MCATL: A Language for Authoring Computerized Adaptive Tests* (Vale, 1985b). This report describes the rationale for the development of elements of the language as well as its formal specification.

Research Report ONR-85-4, *ASCAL: A Microcomputer Program for Estimating Logistic IRT Item Parameters* (Vale & Gialluca, 1985), describes the technical details of ASCAL (for Assessment Systems CALibration), the IRT parameter program included in MicroCAT. ASCAL uses an algorithm very similar to the industry-standard calibration program LOGIST (Wingersky, Barton, & Lord, 1982). It differs from LOGIST in that it runs on a microcomputer and uses Bayesian prior distributions on several parameters. When it is run on an IBM PC with an 8087 math coprocessor, it performs a calibration of reasonable size (e.g., 35 items and 3,000 subjects) in a reasonable amount of time (e.g., less than two hours). When it is run without the coprocessor, the same calibration may take 24 hours.

FIELD TEST OF THE SYSTEM

Implementation of the MicroCAT system at the BE&E School began in June of 1984. A system consisting of 15 testing stations, two network servers, and one proctoring station was assembled. Several tests from the BE&E curriculum were implemented on the system for initial system evaluation.

The entire system was interfaced to MIISA, the mainframe computer in Memphis, Tennessee, which manages all of the instruction at NTC. To avoid reprogramming of MIISA (a task considered nearly impossible by NTC), the testing system was made to look like a GE Terminet terminal, from which MIISA was accustomed to receiving test results. Thus, MIISA was told to expect a new Terminet in the testing room, and the testing network was connected. This technique worked very well; the connection allowed the testing network to get test assignments from MIISA, and MIISA to get test results from the network. The only problem with this connection was that when MIISA failed, no new tests could be initiated until it was fixed. MIISA was the only non-redundant component in the testing system.

Details of the NTC implementation are described in Research Report ONR-85-2, *Implementation of a Microcomputer-Based Testing System in a Military Training Environment* (Vale, 1985a). This report provides details of how the MicroCAT system was adapted to the NTC implementation.

In addition to the NTC implementation, several MicroCAT systems were distributed to non-government users for use and evaluation. While the NTC implementation provided volume tests of the simple parts of the MicroCAT system, these other sites provided tests of the more advanced features of the system.

EVALUATION AND REFINEMENT OF THE SYSTEM

As the system was implemented at the evaluation sites, it was put to use almost immediately. In the early implementations, occasional bugs were found in the system. These were corrected as they were found.

More frequently, however, requests came for additional features in the system. The NTC implementation generated most of the initial requests. These included a request to allow the examinee to skip items early in the testing process and then return and answer them later. This feature was omitted originally because it is incompatible with adaptive testing. However, it is an important feature when the MicroCAT system is used for conventional testing.

Another feature that was implemented in response to requests from the field was the inclusion of high-resolution text-only items. The original system was intended only for medium-resolution graphics items. The addition of this feature made a wider range of textual items possible.

Other features have been suggested and will be implemented in the future. Split-screen text items, in which a reading passage scrolls in the top of the screen while a question remains stationary in the lower portion of the screen, have been partially implemented. Other features that may also be implemented include a hard-copy item banker and random item selection from a domain.

FUTURE PLANS

The MicroCAT Testing System, which was designed and refined in this project, is now a commercial software product. Although it was initially intended for a relatively small group of users (i.e., those who wanted to implement adaptive tests), it appears that the market is expanding. Several good suggestions obtained during the course of the contract will be implemented as revenues allow.

In its current state, MicroCAT is a well-tested, stand-alone adaptive testing system capable of administering a variety of adaptive tests. Since its support is now commercial, the additions that will be made first are those most in demand in the market. Specifically, since the education community appears to be one of the most promising markets, features such as sampling items from a domain, split-screen text items, and conventional item-banking capabilities will be added first. As revenues allow and research suggests, new item types and testing strategies will also be added.

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