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The operational characteristics of a modern equipment facility (random-access multiple-program system) being planned and constructed for the University of Michigan language laboratory and how it compares with the system it is to replace are summarized in this article. A technical description of the structural makeup of the system precedes an extensive discussion of its versatility, with special reference to its specific applications to language laboratories. Concluding portions treat arguments favoring the system and such engineering and economic considerations as program switching and control logic. (AF)

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The University of Michigan Language laboratory has been planning and constructing a modern equipment facility which may relieve a number of present difficulties or awkwardnesses experienced here and elsewhere.

The guiding rules which were set before any work started were:

1. Demonstrable improvement must be achieved in reducing operational fluctuations of the really wasteful sort such as those caused by a speck of dust, a slight mis-adjustment, etc. A book could be written (but ought not!) on the many different types of recurring frustration experienced by students, which defy the earnest efforts of the lab staff to prevent.

2. Operational modes must exist which are required by each of the language departments. Stated another way, equipment ought not be installed which precludes the use by students and teachers of any present or foreseeable techniques. Stated still another way, it ought

not be a subject for debate between the language laboratory and the academic staff as to whether specific programs are feasible due to the constraints of equipment operation. Or again, equipment must be designed which will relax the requirement for each foreign language department to specify, in advance of construction, its manner of future lab use, in that it should be able readily to respond to adopted or experimental materials and methods.

3. Access by students to all functions must be effectively universal. Limiting special modes to certain sections of the lab, or installing all modes permanently to all booths, must be avoided as excessively restrictive and unnecessarily expensive.

4. Instructor supervision must be facilitated for active and passing monitoring.

5. Improvement must be achieved in the physical environment in which the students work.

6. Provision must be made for addition to the system of video, computer assisted instruction, teaching machines, etc., without the need for replacing or by-passing the basic equipment. This does not intend to suggest that renovation or revision will never be needed; it merely states the felt need for an equipment complex which will have as much longevity as contemporary engineering can design.

The plan designed and described by Mr. David Mills in the following article has been carried out, under his supervision, in the construction of an abbreviated RAMP system which is now being used by students at the University. Although the equipment is to be considered experimental in the sense of its use as a demonstration project, and limited to 10 student/instructor positions and 64 programs, the computer and its related components have been installed in cabinets and wired with professional care, so that the work already done by the staff can be used in an enlargement of the system to totally replace the present, out-dated lab.

It should be noted that the expense involved in this kind of laboratory almost certainly precludes its adoption by high schools. Its principal application will be as a useful tool for research and development of methods of lab use at a University, with the future possibility of program distribution to high schools within a limited radius.

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A RANDOM-ACCESS MULTIPLE-PROGRAM SYSTEM FOR THE U of M LANGUAGE LABORATORY

1. Introduction

This memorandum describes the RAMP (Random-Access, Multiple-Program) electronic switching system proposed for installation at the U of M Language Laboratory. The system is intended to provide supervisory control over the several hundred program circuits usable by the Laboratory. These circuits are of three types: 1) master-program circuits for student/instructor use in the monitoring of pre-recorded language drills, 2) utility tape record/playback circuits for student use in imitation drills and instructor use in master-program recording, 3) inter-communication circuits for the purpose of student-instructor-operator communication. The system is designed so that active control of program switching and record/playback equipment is available to both the student and instructor. System expansion and maintenance is facilitated by a modular type of component construction. In the interest of equipment reliability, the system is entirely electronic solid-state in operation and incorporates no electromechanical switching equipment.

This memorandum discusses the application and the operation of the proposed RAMP system. A summary of the operational characteristics of the proposed system and how it compares with the present system will be outlined in following sections. A detailed design description of the proposed system can be found in a companion memorandum entitled "Preliminary Design Specifications for a Solid-State Computer-Supervised RAMP System".

2. System Configuration

The RAMP system contains a collection of program sources, a switching network, and a collection of instructor/student listening booths. For the present the identity of the program sources need not be explicit; sources may include tape or transcription playback equipment, remote pickups from classrooms and lecture halls, or live speech from instructors, students, or equipment operators. The listening booths or carrels contain speakers or earphones for audible monitoring, microphones for responsing and communication and controls for the remotely-located switching and tape record/playback equipment. Student and instructor booths are distinguishable only by use; the electronic equipment in each may be identical. The switching network is diagrammed in Figure 1:

In this figure the program sources are numbered from 0 to 127 and the student/instructor booths from 0 to 149, representing the size of the present laboratory. The RAMP system may grow to several times this. The key element in this system is the switching network, which establishes and maintains the connecting paths between the programs and the booths. The important feature which distinguishes the RAMP system from others is that connection paths may be set up from each booth to any program completely independently from any other booth. It is possible in the RAMP system to establish a connection from every booth to the same program or a connection from each booth to a separate program. The RAMP system then appears to the student as his own private switchboard, one in which a busy signal cannot occur.

Each instructor/student booth is connected to the switching network with multi-circuit cables. Some of these cables are common to all booths, so that separate cable runs between each booth and the switching network are minimized. The booths may be equipped with either earphones or speakers, the volume of which is adjustable from the booth. Microphones, either mounted on the booth walls or slung from a boom attached to the earphone-headset, are connected into the system for inter-communication, sidetone, or responsor purposes. Booth controls include either a rotary or pushbutton dial for program selection, start-stop-record pushbuttons for the remote tape equipment, and signal lamps as necessary. This design will keep the booth free from distracting electronic and mechanical machinery and the equipment itself protected against abuse.

Magnetic tape playback equipment will probably be the principal source of programs in the Laboratory. This equipment may include spool cartridge, reel-to-reel cartridge, or standard reel-to reel machines in any intermixing. Some functions of tape control may be taken over automatically by the switching network itself. For instance, a tape machine which is not in active use at any instant may be shut down, saving wear on bearings, tape, and maintenance. Since the size of the program tape library usually grows larger than the number of tape playback machines available (another application of Parkinson's Law), this practice will allow the equipment operator to keep only the high-use program tapes loaded on the machines as necessary. Low-use program tapes can be loaded on the machines by request from a student/instructor booth. In addition, it is possible, using computer-directed switching, to assign a responsor machine to a booth only upon an individual request from that booth. Such a technique allows a small pool of responsors to serve a larger pool of booths.

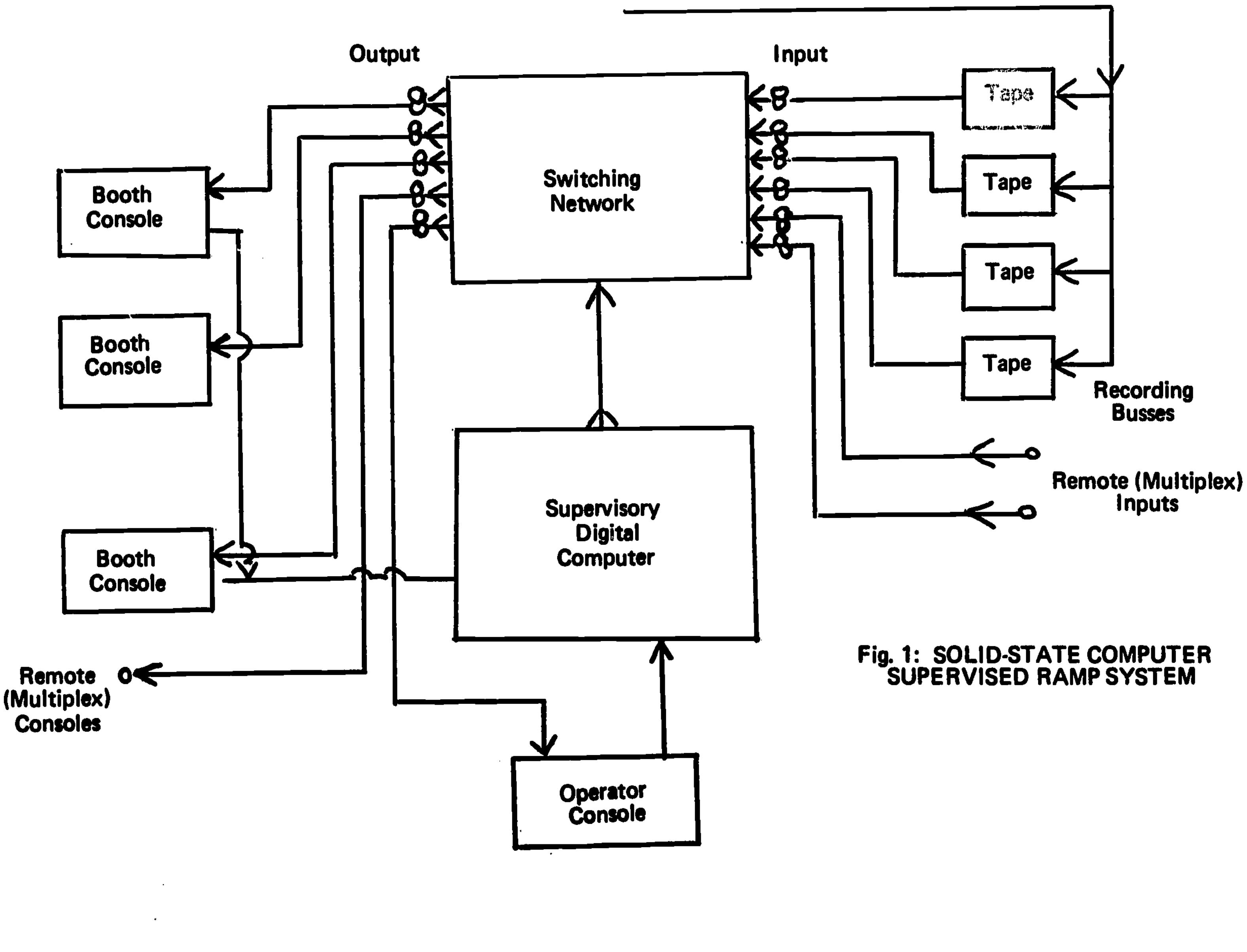

Fig. 1: SOLID-STATE COMPUTER SUPERVISED RAMP SYSTEM

Connecting the programs and the switching network on one hand and the network and the booths on the other is a circuit patching facility (see Fig. 1) consisting of switchboard jacks arranged in tiers. In normal operation these jacks are interconnected by special switches attached to the jacks themselves so that patchcords are unnecessary.

In the cases of special circuit setups, circuit maintenance, or component failure, portions of the system can be reconnected by patchcords inserted in these jacks. As the system grows by the addition of either programs or booths, this patching facility will be invaluable in indicating the need for future laboratory expansion in order to avoid over-saturation of the equipment facilities.

For purposes of generality and simplicity, all patching facilities must operate at the same circuit level and must be as free from operational restrictions as possible. A set of standard circuit conventions define what will be called "system inter-face" rules. Rigid adherence to such rules is essential both for convenient system expansion and external interconnections with remote equipment. This practice results in a justifiable additional expense, since amplifying equipment must be over-designed to allow for conditions considered unlikely in normal operation.

3. Uses of RAMP Systems

Any application involving remote control of selection of multiple program sources is suitable for incorporation of RAMP techniques. Applications, in addition to Language Laboratories, include music-appreciation playback, lecture recording, and intercommunication systems. Applications peculiar to Language Laboratories are discussed below.

3.1. Passive Systems

The present use of most Laboratory facilities is one of passive monitoring or listening. Here the student is equipped with a pushbutton dial or other divice to signal the centralized switching gear the program to be connected to the student's speaker or earphones. No other information may be transmitted by the student/instructor to the system. In particular, if responsing operation is required, the responsor equipment must be installed in the booths and operated directly by the student/instructor. Such an arrangement, one in which the student may select his own program but not control any external devices, will be called a passive monitoring system. This type of system can be developed and built by responsible industry sources using state-of-the-art solid-state logic and switching components, although in-house Laboratory development is entirely practical and far less expensive.

It is possible to inject a degree of versatility into the operation of passive systems. For example a special instructor booth could be equipped with an intercommunication console with which an instructor can converse with his students and possibly a tape recorder with which he can record their responses. Using RAMP techniques the special console need be only a pushbutton dial similar to that installed in student booths but having access to additional "programs" which are in fact derived from microphones installed in the student booths. This type of operation is readily added to a passive system.

The intercommunication system might readily be expanded to include the equipment operator, so that the student/instructor could request a little-used or special tape program to be loaded on a playback machine. This design would reduce both the initial investment in playback equipment which would stand idle most of the time and allow for system overloads due to growing pains.

3.2 Active Systems

An active RAMP system includes provisions for the student and instructor to control the remote record/playback tape equipment. Such a system allows the student/instructor to perform many additional functions as well as single switching requests. Anticipated functions available to the student include those of stopping and starting the playback equipment in response to instructor or machine requests for additional drill, initiating a responsor cycle for record/playback of the student's own vocal responses, and initiating auxillary functions such astape-to-tape dubbing for later playback. Anticipated additional functions available to the instructor include override control of the student functions in the case of programmed remedial drill or individual assistance, recording of sample student responses for later playback, and master-tape recording for later monitoring playback.

It is obvious that the active system involves a degree of design and operational sophistication well beyond that of present systems. Such a system allows an unparalleled generality in many directions. For instance: 1) the playback and responsing equipment and student/ instructor booths can be unilaterally added to the system either locally or remotely without major reconstruction transients. 2) Since any student monitoring/responsing booth can be used in addition by an instructor for student monitoring or master-tape recording, investment in special facilities for these purposes is unnecessary.

Most significantly 3), delicate and expensive tape-handling machinery may be moved out of the booths and centrally located convenient to the master-tape library. The machines may be loaded directly by an equipment operator - students need never handle the tapes.

4) Should master-tape duplication be necessary for individual student use in start-stop responsing drills, the process can be initiated automatically by the student, saving operator involvement in manual program patching and easing inventory control on the tape spools themselves. 5) It becomes possible to reduce the number of special tape devices such as responsors, since the switching network can assign and release individual responsor machines as required by the instantaneous individual booth demand. Finally 6) since unused machines can be shut down, it is convenient to keep a running record of actual program use for purposes of facility and course planning and evaluation.

This type of system, one in which the student/instructor has active control over remotely-operated tape equipment, is, so far as known, not under consideration for development by any responsible industry source, nor can any known existing system be economically modified to include such features. Using the technology of state-of-the-art computer developments, however, it seems both feasible and practical for the Laboratory itself to undertake the development of such a system. More on this topic will be offered in a later section of this memorandum.

3.3 Blue Sky Department

An additional, yet speculative, comment may be appended to this section. As interest, use, and understanding of data and decision processes increase, it is extremely likely that the educational and social sciences departments of the University will support faculty research into what has been called "programmed instruction". (This term should not be confused with the term "computer-directed switching" used in this memorandum in connection with the switching network.) The use and support of RAMP facilities in thesis research in education, linguistics, and psychology is obvious. The organization and design of RAMP systems is tailor-made for use as a tool in this research. Since the design of state-of-the-art RAMP systems such as proposed here make extensive use of computer-type circuits and techniques, then the interfacing of external computing-type equipment is convenient and cheap. For instance Auxilliary observer-operated devices such as typewriters, response-time measurement devices, and various forms of stimuli can either directly actuate or be directly actuated by the switching network.

4. Operational Implications

One of the most persuasive arguments in favor of RAMP systems is the convenience and economy of centralized program-tape handling. A single non-technical equipment operator can reload the tape machines from programs kept in a convenient tape library adjoining the tape-machine area. The frequency of machine reloading is of course a function of both the number of playback machines available and the size of the current tape library. The programs pre-recorded on these tapes will be instantly available to all student/instructor booths for monitoring purposes but cannot be started or stopped under student control.

In addition to the pre-recorded programs which, presumably, are available to an individual booth either immediately or after a short delay for machine loading, a pool of record/playback machines will be available to the laboratory-at-large. The assignment of a particular machine in this pool to a particular booth is accomplished either manually through the patching facilities or automatically through a computer-directed switching network. It is assumed that the assignment of a machine to a booth includes the active control by the booth occupant of the machine operation. The occupant will be able to perform record, rewind, and playback functions for purposes of dubbing a master program tape or responsing to either the master program tape or a master program tape dubbed on the machine itself.

It should be emphasized here that active tape handling is done only by the equipment operator, and even then only to provide the peak-overload flexibility required for economical and efficient machine utilization. The student/instructor never needs to handle the tape or to wrestle with recalcitrant, unfamiliar, tape-handling machinery. Yet he has full operational use of record/playback/monitoring facilities as if he had his own private machine. In addition, and this is one of the most salient points, each student/instructor has this operational flexibility no matter which booth he happens to be occupying, whether adjacent to the tape library or a mile away in a dormitory.

Such a system can grow "gracefully." As the program and booth requirements become larger, additional equipment can be added without disrupting the existing system. If initially only the program playback machines are installed, then the record/playback pool machines can be added in small batches. The problem of assignment of pool machines to individual booths would be an administrational one. Probably only a limited number of courses would need to make use of of the responsing facilities anyway. The operator (or computer) could make the actual connection upon identification and request of a booth occupant.

Should remote facilities be added to the laboratory, say at housing units on Main or North Campuses, then these facilities can have all functions available to the existing facilities; yet without extensive investment in tape equipment. The inter-connection between the local and remote facilities can be via leased telephone circuits or by laboratory personnel-installed cables, depending on the distance and route accessibility. Conventional data-transmission, telemetry, and multiplex techniques can be employed where practical and economical.

5. Engineering and Economic Considerations

The passive RAMP system described above is available from a number of responsible industry sources, although not in the full generality implied in the description. Existing engineering techniques appear to be severely wanting, however, in flexibility of expansion and freedom from minor maintenance ills. The active RAMP system described is not known either to exist or to be seriously considered for development by any source. Extant conventional passive systems can be modified only at considerable expense. Most of the problems of expansion, modification, and maintenance in conventional systems can be directly traceable to the electromechanical switching devices incorporated in their design. Although permitting certain economies in fixed system design, these devices are bulky, power-consuming, electronically and mechanically noisy, and require frequent maintenance for contact cleaning and adjustment.

Electromechanical devices used extensively in conventional switching system construction fall into two classes that of the actual program circuit switching and that of the control logic used in the line-finding and switch-actuation circuitry

It is the goal of a current developmental program at the Laboratory to find ways of replacing electromechanical devices used for these purposes. The current status of this program is summarized in following sections.

5.1 Program Switching

The most critical and expensive single device used in the Laboratory is the program switch. This may be considered a single-circuit, several hundred-line remotely-actuated audio switch. Existing designs borrow from the technology of the telephone industry. The step-by step switch (stepper) and crossbar switch are familiar and well-developed telephone devices suitable for this application; however, the flexibility demanded by RAMP systems force design compromises which limit the inherent capabilities of these devices.

State-of-the-art developments in computer technology have produced improved solid-state devices which can replace the older electromagnetic devices yet are free of most of their problems. To be sure, the new devices are more expensive and more difficult to obtain, but their use allows economies in other parts of the system which to a great extent offset their higher cost. A preliminary design for a solid-state switch which can be used in program-switching circuits has been developed by the Laboratory. These relatively inexpensive switches are arranged in multi-dimensional arrays called crosspoint matrices. One of these matrices is under the control of each student/instructor booth in the system and may be used to connect that booth to any of up to several hundred programs.

The crosspoint switches themselves are assembled on printed-circuit modules of a glass-epoxy substrate. The molules are plugged into a special rack which contains the machine-wired module interconnections. An assembled matrix of typical size, say for 256 programs, occupies a three-dimensional space of roughly 12 inches by 6 inches square.

5.2 Control Logic

In conventional switching systems, a device called a line finder is used to connect the student/instructor dialing device to the appropriate switch and perform the switch actuation. For economic reasons the line finder is shared among several booths which must then compete for its seizure. After seizure by a particular booth, the conventional line-finder accumulates and processes the dialed digits until the program has been completely dialed. Only then is the line-finder released from the booth and made available for other booths. One of the most convincing demonstrations of the utter inadequacy of these conventional systems for active RAMP application is to wander about an existing Laboratory dialing only a single digit at various student dialing stations. The system speedily hangs up so that nobody can dial anything until special time-delay relays release the line-finders from the partially-dialed stations. In conventional systems the occasional delay imposed is only a minor irritation, but in the active RAMP system it is crucial since it occurs whether the student/instructor is waiting for dial tone before dialing a program or accessing and controlling a responsor machine.

What is needed for active RAMP system application is an extremely fast processor which can sense the digit dialed for either program selection or tape machine control before the student's hand leaves the dial or pushbutton. Such a processor would have to have a fast internal memory which could record the digits as they are dialed (possibly from many sources simultaneously) and the identity of the dialing party. As each program dialing sequence is completed, the processor would access the matrix switch and perform the switch actuation. If the device were fast enough, then only one such would be required for the entire Laboratory.

This processor may be a small general-purpose digital computer. The computer can, in addition to the operations of line identification, digit storage, and switch actuation, perform bookkeeping tasks of responsor machine assignment, playback machine shutdown, and diagnostic circuit checkout. Essentially, it becomes possible to mirror the status of all the machines and switches in the system in the computer's high-speed memory, and perform sophisticated decisions under program control. Programs for the computer, probably punched on paper tape by peripheral equipment, could be easily changed, allowing an exceptional latitude in flexibility without physically rewiring the system.

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