HEWLETT PACKARD

APPLICATIONS OF COMPUTERIZED DIGITAL DATA ACQUISITION SYSTEMS

Minicomputer system aids busy psychology lab

A Solution to a Measurement and Control Problem for: UCLA
Psychology Dept.
Los Angeles, Calif.

A view of the Psychology Department facilities at UCLA. Franz Hall (left), newest in the three-building complex, also houses the department's computer system.

Minicomputer system aids busy psychology lab

A trip through the facilities of the Psychology Department at the University of California in Los Angeles would, at first glance, reveal not much more than a modern structure bustling with the usual day-to-day classroom activities. Not so easily noticed, however, are the department's extensive experimental laboratories where a wide variety of psychological research studies are being conducted. Here the undergraduate student may be working on a laboratory project to expand his knowledge gained in the classroom; a graduate student may be found compiling experimental data in his particular area of interest to provide the scientific documentation needed for his thesis; a faculty member, in conjunction with graduate students, may be conducting investigations into areas of basic scientific research providing data on some of the lesser known psychological phenomena.

Experiments of this nature most commonly involve human responses to precisely controlled stimuli. Successfully measuring these responses and storing them for subsequent analysis is, of course, essential for achieving meaningful results. Because of the variability encountered with human responses obtained under fixed conditions, it is often desirable to introduce sequentially-controlled patterns of stimuli as a function of previous responses, and to collect large amounts of data in order to form a sound basis for analysis.

Traditionally, arranging the apparatus for presenting stimuli and recording responses, setting stimulus parameters during an experiment, keeping track of responses, tabulating data, and performing data analysis have been direct responsibilities of the experimenter. He has tediously performed these tasks by mechanical, optical, and electronic techniques in assembling apparatus for the experiment, by manual settings of analog stimulus and recording equipment during the course of the experiment, and through manual analysis of records and other methods of data analysis following the collection of data. All this diverts the experimenter from the main task of meeting the conceptual demands of his research, as well as limiting the rate at which complex tasks can be performed in the experiment.

It is now feasible, for many types of experiments, to fabricate highly general laboratory control and recording systems that preclude the necessity for arranging apparatus to meet individual experiment needs. *The control and recording parameters for each of a wide range of experiments can be determined through programming of the Psychology Department computer system with little expenditure of time, effort and equipment funds.*

Human experimenter limitations are no longer a major barrier to collecting large amounts of data, or to the design of experiments involving rapid stimulus settings and complex dependencies of present stimulus conditions on prior subject response patterns. Now, these formerly manual tasks can be performed automatically with the department's computer, thus freeing experimenters to focus attention on more significant aspects of the research, and to give more immediate attention to the subjects themselves.

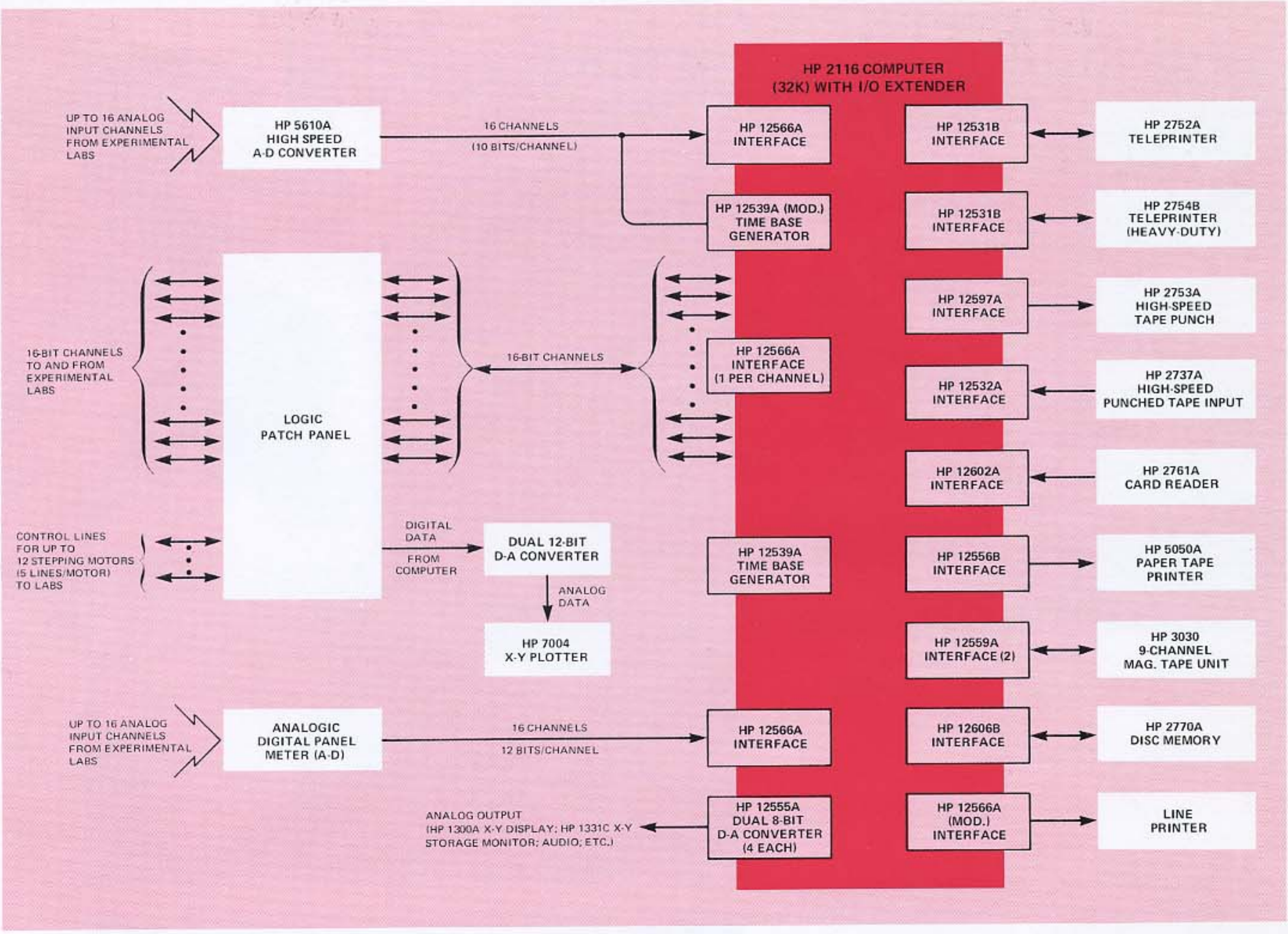
Specifically, the department's computer system provides: (1) *on-line, or real-time, collection of experimental data resulting from subjects' responses* and (2) *control of the experimental apparatus so that stimuli can be automatically changed as required*. For maximum utilization of the computer system's intended purpose, it is used for only a minimum amount of off-line data processing. Provision is made for extensive data processing at either of two large computer installations on campus.

CONFIGURING THE SYSTEM

In the initial design stages of the Psychology Department building program, Prof. George Mount, currently heading the Psychology Computer Use Committee, was instrumental in defining the needs of the department to insure that consideration be given to the fact that the several experimental labs would later be connected to the computer system, also in the building. This was accomplished by means of a system of ducts, built under the hall ceilings, through which cables are run to interconnect the various labs and the computer system room. Space is saved by using flat cables which terminate under removable floor tiles in the labs. The cabling system offers the experimenter a convenient and simple method of interconnecting his apparatus to obtain maximum use of the computer facilities.

Complementing his attention to the building construction details, Prof. Mount made an in-depth study of available digital control systems which could supply the department's needs. His findings were summarized in a report (1968, unpublished). Essentially based on a minicomputer as the primary control source, the report concluded that a Hewlett-Packard computer system best fitted the department's needs. (Some of the determining factors that led to this selection are discussed later.)

The block diagram shows the computer and associated instrumentation comprising the hardware installation in the computer system room.



At the heart of the system is an HP 2116 Computer with 32K 16-bit words of memory. A heavy-duty teleprinter is used for general purposes of communication with the system. A second teleprinter is for limited intermittent purposes such as punching source program tapes, edit files, etc., and for occasional interactive use in experiments. The high-speed paper tape punch is used whenever a paper tape copy of either an edited source or binary program is desired. The high-speed punched tape input (reader) is used to read source and binary programs, data, long edit files, etc. into the system. The card reader accepts machine-punched or pencil-marked cards for input to the computer. The cards, specially printed with optical timing marks, can contain data which may be read into the computer for simple analysis, or the data may be transferred to magnetic tape for in-depth processing on a larger computer. Similarly, the cards may contain punched or written programs for compilation or assembly. (Other uses for the card reader are described later.) The paper tape printer provides numeric data printout. The magnetic tape unit provides read and write capabilities in an IBM-compatible 9-track format. The disc memory is used for long-term storage of system and user programs and subroutines. Programs stored on the disc are swapped into core for execution and then returned to the disc. The line printer is used for high speed printing of data, program listings, and similar information. Edit listings and program listings are printed at the time of editing, compiling, or assembling, if requested. The X-Y plotter is used for high resolution graphic reproduction on 11″ x 17″ paper.

The entire system is under control of the HP real-time executive (RTE) software operating system which allows the Psychology Department to conduct experiments in a real-time, priority-oriented, multiprogramming environment. *With the RTE, the computer controls a number of experiments simultaneously in the real-time mode and at the same time allows low-priority activities such as program compilation, debugging, data conversion to magnetic tape, card reading, etc. to take place.* Real-time collection of experimental data and control of devices is handled in a section of computer memory designated as foreground, while low-priority activities are handled in the background area of core. Most of the real-time programs are of a relatively slow nature and, as such, are stored on the disc memory (disc resident) and swapped into core for execution as needed. Where faster access to the computer memory is required, the user program is assigned to core (core resident).

DESIGNED FOR VERSATILITY

As mentioned earlier, a good deal of forethought has gone into defining the department's needs and the instrumentation required. Combining the hardware and powerful RTE software system with a third factor – a resident engineer/programmer, Mr. Sol Rothkopf – the department has an extremely efficient and highly productive system with versatility to handle a great variety of experiments.

Each laboratory (and thus each experimenter) has available a wide choice of measurement, control, and recording capabilities. Mr. Rothkopf has made it a regular practice to be available to experimenters, particularly in the initial planning stages of a project, to assure that full advantage is being taken of the department's facilities. Some of those presently available are listed below.

- Duplex Input/Output Channels. Normally one 16-bit duplex channel is assigned to a lab; however, additional channels can be assigned if needed. Inputs are used, for example, to record a subject's responses or other experimental information such as switch closures, keyboard functions, etc. (Each lab is equipped with a 12-character keyboard to provide communication with the computer.) Outputs are usually used for operating optical shutters, relays, tone generators, etc. The experimenter has a great deal of flexibility here since there are as many as 2^{16}, or over 64,000, possible inputs and outputs on each channel.

- Analog Input. A lab may be connected to the computer to utilize two analog-to-digital converter systems. The first system, HP 5610A A-to-D Converter, is used for high-speed acquisition such as in physiological work, where up to 1,000 samples/sec may be collected with 10-bit resolution. To add greater versatility to this system, an RTE driver has been written in both 8- and 16-channel versions in a multiple use mode where all channels can be in use at the same time. The driver also incorporates the "privileged" interrupt feature (described below) of the RTE. The second system uses a digital panel meter for applications where less speed and less resolution are required such as galvanic skin response recording, monitoring light levels, and recording subject's analog responses.

- Stepping Motors. Stepping motors are assigned to individual labs as needed and connected to the computer by a set of 5 wires. Up to 12 motors can be operated simultaneously. User-written programs can step the motors any number of steps in either direction to control various experimental parameters such as optical wedge density, stimulus position, etc. Motors can also be programmed to step continuously until told to stop (for example, by a subject's response), all the while keeping a record of the number of steps taken, or step until a microswitch is closed.

- Carousel Projector. A random-access slide projector can be programmed to display any one of 80 slides on request. The user can also program display orders and durations to be dependent upon the subject's responses or any other factor.

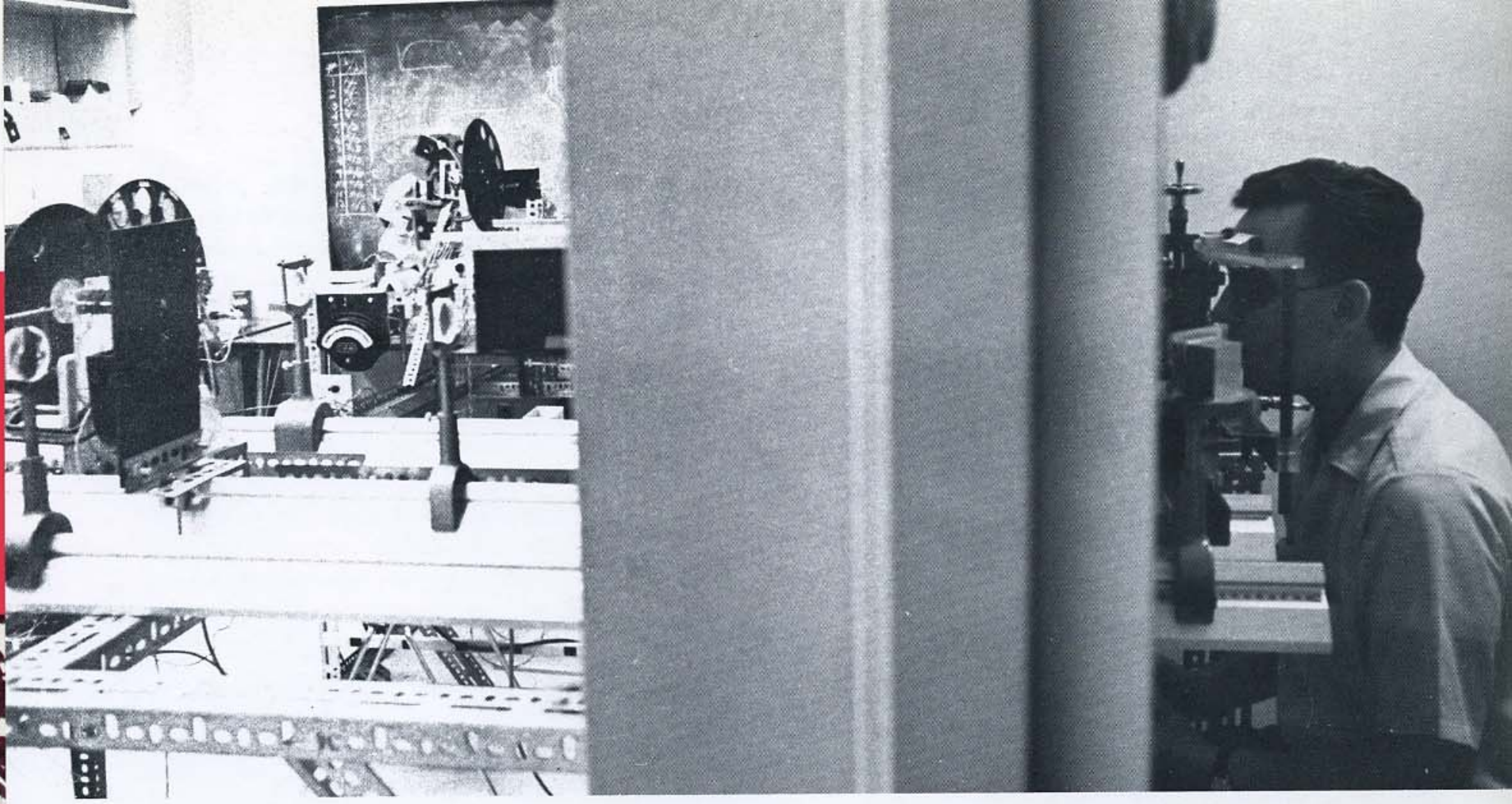
- Card Input. In addition to the applications previously mentioned, the card reader is also used for grading exams and for recording and analyzing the results of questionnaires used in psychological studies (usually done in the background area of core). The department presently has available printed cards for multiple choice testing which allow sixty 5-choice answers per card, plus identification; another card provides for 180 true-false answers.

- Magnetic Tape. Capability is provided to randomly access digitized visual and auditory stimulus control signals which are stored on magnetic tape.

- Displays. The computer is used to produce simple geometric patterns for visual display either on an oscilloscope or on an X-Y plotter. Programs are available for standard character generation on the plotter; these are used for stimulus display in off-line experiments or for preparation of graphs of experiment results for articles and papers.

- Tone Patterns. Software and specially designed hardware interfacing allow input from a 48-key organ keyboard and output of tones through a digital-to-analog converter. The computer provides: (1) control of waveform and pitch scales through software, (2) signal light feedback to the operator, (3) a running account of his performance, and (4) new patterns as a function of prior performance. The system is designed to aid in the instruction of music students, and for the experimental study of perception and memory for tonal patterns. The important advantage of this system is the provision for software control of waveform and pitch in creating tonal patterns.

When an experiment is ready, the system programmer assigns it a priority to prevent possible delays resulting from simultaneous demand for execution of programs. Priorities are assigned on the basis of maximum allowable critical delay. Programs set up to operate at arbitrary time intervals use the normal interrupt system; however, for programs requiring immediate service, the "privileged" interrupt is used. This feature of the RTE holds off lower priority system interrupts while the interrupt system is enabled to allow any of the privileged interrupts to be processed.



The department's computer controls apparatus in a visual perception lab and measures and records a subject's responses.

SELECTING THE SYSTEM

Besides making a point-by-point comparison of main features, Prof. Mount's report included a general discussion and evaluation of the systems considered that led to selecting the HP computer system. Three of the important factors in determining the final selection were as follows:

- HP computers have a highly versatile priority-interrupt input/output structure that is exceptionally straightforward and easy to understand. All complex timing and channel addressing is handled internally in conjunction with standard 16-bit input/output registers. Each register furnishes a dual 16-bit input and output channel for data received from instruments and for instrument control signals. The design allows for ordinary wiring from the computer to individual laboratories in most cases; the need for specialized cabling is determined by the demands of the experiment itself. This is of prime importance to users, such as students, who must design and conduct their own experiments without specialized knowledge of system operation.

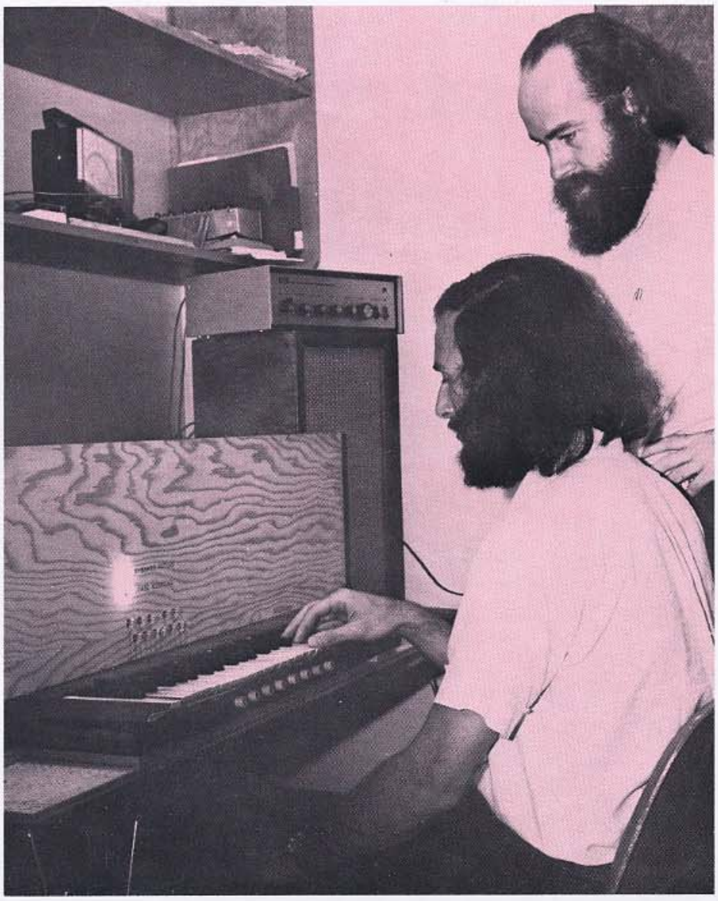
- HP computers allow easy expansion of the basic system plus compatibility with a wide range of peripheral devices. As familiarity with the system increases and the number and types of experiments increase, the ability to expand the system to meet future needs is a very important factor.

- Internal compatibility of the HP computer line is an important factor in providing for easy interchange of facilities and programming with other HP laboratory computer installations in the department.

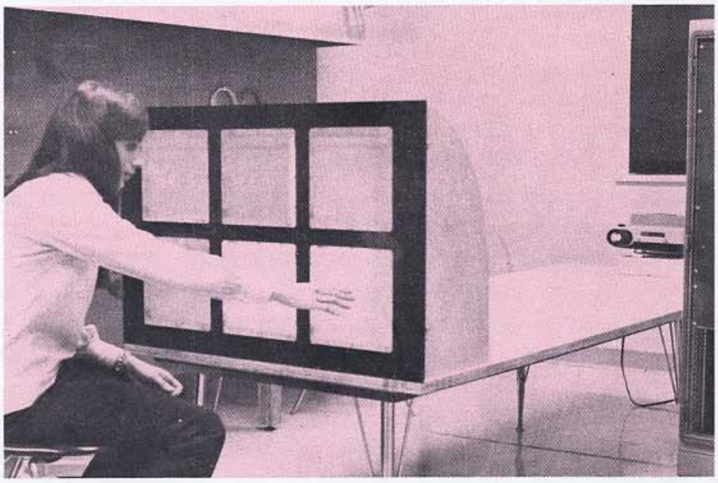
The extent and range of uses of the UCLA Psychology Department computer facility attest to the value of such a system in an academic environment. Placing the experiment control needs of the students and faculty uppermost in design of the facility has resulted in a highly satisfactory system with capabilities for expansion to handle future needs.

The system programmer, Mr. Sol Rothkopf, discusses programming techniques with a member of the faculty (Prof. Wickens), seated at the teleprinter console, during the initial planning stages of an experiment.

Seated at the organ keyboard, a graduate student is taking part in the tone patterns perception and memory experiment, under the guidance of Prof. Dowling. The student is repeating computer-generated tone patterns heard over the speaker. Tests usually start with simple patterns and progress to more difficult and unusual patterns which may be compressed or expanded, in accordance with individual abilities.



An experimental setup intended for pattern/color recognition testing of autistic children is checked out by the student in charge. The department's computer controls the arbitrary-access projector and records responses from subjects who press a screen corresponding to a pattern or color as called for by the experimenter.



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