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FINAL REPORT
LINC EVALUATION PROGRAM

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FORWARD

This report is a final report submitted to the United States Department of Health, Education, and Welfare in connection with their LINC Computer Evaluation Program. Under their Grant No. FR 00151-01, the Instrumentation Research Laboratory was supplied with a LINC Computer and some additional accessory equipment. The applications of this computer and its evaluation represent work carried out under National Aeronautics and Space Administration Grant NsG 81-60. For this reason, this report is being submitted both to the LINC Evaluation Board in fulfillment of their requirement for a final report and to NASA as a technical report.

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I. INTRODUCTION

The Instrumentation Research Laboratory within the Department of Genetics has as its purpose the design of special purpose instruments for biological research. This includes electrical, mechanical and optical design. The LINC in our laboratory has been used as a system element in a number of experimental situations and its use has proven to be both education to us and experimentally rewarding.

Headed by Dr. Joshua Lederberg and under the direction of Dr. Elliot Levinthal, the laboratory has as its primary mission the development of life detection systems on a microbial level for remote Martian exploration. In order to accomplish this end, a number of different types of physical measurements have been investigated in great detail. We believe that these studies, a number of which involve LINC, will also result in new instrumentation and techniques of general laboratory utility.

We wish to request that the LINC be permanently assigned to our laboratory.

II. GENERAL USAGE I-O EQUIPMENT AND PROGRAMS

Our LINC has been equipped with a number of peripheral devices. These include a Datamec IBM compatible tape recorder, a Calcomp plotter, and a teletype. In the process of being installed is a 4096 word external memory.

The Datamec is equipped for two speed (45 and 4.5 ips) two density (200 and 566 bpi) operation, with both read and write capability. These speeds and densities give us a wide range of data rates. The upper limit is 25,000 six bit characters per second. The interface is very simple and required only two cards. One of these would be eliminated if the gated accumulator lines were being used for nothing else.

Programs for the Datamec include those to read and write IBM compatible format, generate data tapes from continuous on-line input, and to regroup the input data on LINC tape blocks and then, if desired, to rewrite these blocks into IBM format. All of these combinations form a highly flexible system. Use of the Datamec has completely superseded the IBM 026 keypunch.

The Calcomp plotter has been in operation for some time now and has proven to be extremely useful. Programs for plotting all forms of data have been written. These include both ordinate and abscissa scaling and linear interpolation. A program has also been written for character generation which includes character size scaling and positioning.

The teletype has proven to be a very good means of getting both program and data into LINC and getting hard copy of both out. Its major drawbacks are its low speed, lack of tabs and that it is somewhat noisy; however, we know of no cheaper means of getting printed output. Input and output routines have been written which calculate teletype code from LAP code and viseversa which take about twenty locations each, so memory usage is not excessive.

The 4096 word memory, which should be in operation within the next few weeks, will be used both for program and data handling. There will be three modes of operation which are: 256 word input and output gulps at eight microseconds per word and single word input which indexes the memory address register with each input. This later mode is designed mainly for data handling.

III. UTILITY PROGRAMS

These programs include those for program input, assembly, and debugging, for keyboard data input and computation and for data display. Most of the programs to be mentioned are more completely described in Appendix A.

The LINCT system is our teletype program text input-output system which has a number of useful features. It is tied into a modified LAP which will assemble for the 2K memory.

We have operating on the IBM 7090 a compiler for LINC which uses a modified Balgol language. This system, called "BLINC", and a program operating system which was written in BLINC are described in some detail in the appendix.

Debugging routines include an octal to Mnemonic converter and print-out program, and a program which follows another program through all of its branching to determine which locations contain instructions and which contain constants. This is used with the converter program to get a proper print-out. A print-out of LAP III was obtained in this way.

A Floating point package with two word mantissa has been written. Copies of this program and a usage explanation will be available shortly. This program has been incorporated into a desk calculator with storage routine. This routine has the usual arithmetic operations as well as square root, e^{X}, $\log_e X$, sin X, cos X, and 2 X 2 Chi square. It is arranged for the easy addition of other arithmetic subroutines. Teletype input and output and certain manipulations of the stored data are included.

A number of simple algebraic programs have been written, such as those for mean and standard deviation, C i square and other statistical operations.

Display programs include those for point and bar graph display with X and λ scaling keyboard calling of data sets. These data sets may be manipulated in a number of ways including inversion, addition, multiplication and rotation.

These are the major programs of a general usage nature now in operation. The only major programing effort now being considered in this class is a simple arithmetic compiler based on the two word floating point system. A more complete symbolic compiler is a possibility, but due to the large amount of effort involved will probably not be undertaken for some time.

IV. EXPERIMENT RELATED PROGRAMS AND HARDWARE

Most of the research in our department is involved with experimentation either on a bacterial or molecular level; therefore all of the on-line LINC experiments that have been done have involved physical methods such as mass spectroscopy, radioactive and fluorescent tagging, fluorescent decay times and particle counting. An anticipated experiment involves the interpretation of Raman spectra.

The LINC has been directly connected to the output of the Bendix time-of-flight mass spectrometer. Output from the mass spectrometer is reduced as it comes into LINC into mass amplitude and time of occurrence. The direct determination of mass number is difficult due to instability in the Bendix's scanning ramp. One means of overcoming this, which will be tried, is to allow LINC to generate the scanning ramp by the use of a mechanical D-A converter which has been built in our shop. This consists of a 200 step per revolution stepping motor driving a ten turn pot. This is a very simple system and has proven most useful. This use of LINC ties in with a much larger system which is a computer program for the direct determination of compound composition from mass spectra. This work is being done under a separate grant and the initial program is being run on the IBM 7090 at the Stanford Computation Center.

The LINC has been used in a number of ways in experiments with fluorescent compounds. The first experiment of this type used LINC as modulator, phase locked detector, and integrator in an extremely sensitive fluorometer. With integration times of ten minutes, the detection of 10^{-13}

molar solutions of fluorescein with a signal to noise of 15 to 1 were obtained using a 400 milliwatt light source. This experiment was performed to determine parameters for a sensitive fluoremeter as part of our effort to design apparatus for the detection of life on Mars. A program is now being written which will determine the best fluorescent system transfer function for a given material by generating all possible combinations of filters, light sources, and phototubes. The data for the components of this system will be stored as sets on LINC tape.

A system has been built for the determination of fluorescent decay times in the low nanosecond region. This consists of a fast flash lamp, photomultiplier tube, sampling scope and LINC as a 512 channel integrator. Calculation shows that we will get about two quanta per channel per flash. Our design goal is to investigate materials with decay times on the order of five nanoseconds. To date, our best results have been in the 10 nanosecond region. The limiting factor is the lamp decay time. This will be improved by the use of a different type of lamp. The LINC has performed most admirably in this application. No external hardware was required except the mechanical D-A convertor for driving the sampling scope sweep. This experiment is being conducted in cooperation with Dr. Lubert Stryer of the Stanford Biochemistry Department. A program will be written to get a best exponential fit to the experimental data so that direct time constant output will be available.

Programs have been written for the keyboard input of data from nuclear counters which determine man and standard deviations as well as sorting data sets according to size distributions and normalizing the data. These programs have been in routine use by a group in the Genetics Department under the direction of Dr. Leonard Herzenberg. This group is studying antibody reactions in mice.

These programs have, by the rapid presentation of results, allowed the experimenters to determine what the next step in their procedure should be with very little delay, and has therefore increased the number of experiments which they are able to perform by a factor of two to three.

V. THE LINC EVALUATION PROGRAM AS A TRAINING TECHNIQUE.

In general, the experience gained with digital techniques has been of great value to all of us here. The instruction initially received on LINC was quite adequate with one exception. It would have been very desirable to spend more time on use and misuse of the various I-O functions. It has been in this area that most of our nonproductive time has been spent. From the overall point of view, LINC has been a most demanding teacher in its own right. It has changed and simplified our approach to many problems. It has also made possible experiments which would otherwise have been too time consuming to perform.

Several undergraduate and medical students have gained proficiency in systems programing on LINC. It is an excellent machine from the standpoint of man-machine interaction but higher level languages would give a more realistic interaction to sophisticated systems.

VI. COMPUTER PERFORMANCE

The performance of LINC in respect to maintenance has far exceeded reasonable expectation. After approximately 3200 hours of operation, the only failures have been one bad cable connection and two output transistors whose failure can be traced to external misuse.

The general performance of LINC in the laboratory has been entirely adequate and most rewarding. Most of the recommendations that come to mind must be admitted to be generated by our own special requirements; however, there are three recommendations which it is felt are of general interest to most users.

The first area is that of multiple word arithmetic. Any instruction changes which would reduce program length and running time would be a great help. These might include clearing the accumulater on a LAM instruction and recovery of both halves of a multiply.

The second suggestion is to make all of the 2K memory programable. This would be very useful when performing complex computations and would reduce the running time of a number of programs which we now operate by minimizing the number of tape transfers involved. A suggested means of achieving this is being transmitted under separate cover to S.M. Orinsten at the Computor Research Laboratory.

Our third point is that a problem-oriented compiler (e.g. artran or Atyol) would be extremely useful. Even if the compilation were somewhat slow, the reduction in programing time should still be very large. Mnemonic print-outs of the compiled program can allow the programer to see exactly what is happening and give him a framework in which to get machine code zonations.

VII. CONCLUSIONS

The concept of what an ideal laboratory computer should be will vary greatly among various investigators. From our point of view, LINC has proven to be a very useful system. The careful attention of the designers to those points which are most important for the on-line use of a computer is obvious and most gratifying.

It has become apparent that in the future we will want to have on-line computer capability even greater than that provided by LINC. Greater word length, higher A-D resolution, larger memory, greater speed and smaller physical size will be the types of improvements that we will be looking for in new machines. A system such as IBM's 1800 is a step in the right direction. This desire for a larger capability has certainly been the result of the use of LINC itself. We feel that future developments must proceed in this direction if full advantage is to be taken of the experience gained from the LINC program.