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E) Funding Support

The Rutgers Resource is funded through an NIH grant: Research Resource on Computers in Biomedicine. The NIH grant number is P 41 RR643. The Director and Principal Investigator is Dr. Saul Amarel of Rutgers--The State University of New Jersey.

This grant is in its third renewal extending for three years from December 1977 through November 1980. The total amount of the award for this period is $1,426,598 in direct costs. In the current year, December 1979 through November 1980, the funding level of direct costs is $451,383.

II. INTERACTIONS WITH THE SUMEX-AIM RESOURCE

A. Medical Collaborations and Dissemination; Interactions

The SUMEX-AIM facility provides one of the nodes where a good part of our collaborative program development and testing takes place (the other facility is RUTGERS/LCSR). These medical collaborations are described in I.B. above.

An important responsibility of the Rutgers Resource within the national AIM community is to sponsor dissemination and training activities. The focus of our efforts in this area continues to be centered around the AIM Workshops and sessions on AIM research at national and international conferences.

As part of our collaborative activities with SUMEX-AIM in this area, we have continued our contribution to the preparation of the AI Handbook.

In order to increase the dissemination of AIM work within specialty fields of medicine, we have also presented tutorial papers at relevant conferences.

1) Fifth AIM Workshop (1979)

The fifth Annual AIM Workshop differed from the ones preceding it. It was a mini-workshop devoted to a single sub-area of AIM research: medical consultation problems and systems. This year, responsibility for the organization of the miniworkshop rotated to Dr. Peter Szolovits of MIT, with the intention that a system of rotation for the hosting will now develop (next year's will be held at Stanford). The Rutgers Resource retained a coordinating and funding role: Dr. Kulikowski worked with Dr. Szolovits in the organization of the miniworkshop, and the Resource covered the travel expenses of a number of AIM groups and individual participants.

The miniworkshop took place at the Talbot House, S. Pomfret, Vermont on May 7-20, 1979, and attendance was limited by a number of people that could be accommodated. A deliberate attempt was made to include only those investigators from medicine and computer science involved in the day-to-day activities of AIM research. Participation by graduate students was encouraged. there were 32 attendees, including 11 computer scientists, 14 graduate students and 7 physicians. In contrast to previous workshops, the concentration on a single research area allowed greater depth of discussion, and encouraged more informal interchange of ideas and opinions. It also served an important training function for graduate students and junior AIM researchers, who were not able to attend IJCAI because of its distant location (Tokyo) this year.

The general structure of the miniworkshop was as follows:

a) Five technical sessions on computer science issues of the representation of knowledge, explanation and justification, knowledge base acquisition and maintenance, and the computational methods of INTERNIST-11.

b) Three general AIM sessions on the assessment of the current state of progress of AIM methods and programs; the sources of difficulties in bringing these programs to clinical application; and an experimental discussion of knowledge-acquisition problems centered around a simulated CPC-style protocol analysis.

The miniworkshop format was successful in encouraging a more intimate exchange of ideas among workers in this AIM subfield. It would be desirable to hold other miniworkshops in the future in application areas such as psychology and biochemistry as the interest of the AIM researchers dictates. The format of a general workshop for all groups should probably be reserved for less frequent meetings.

2) AIM-Japan Workshop:

A one-day workshop was organized by Drs. Kaminuma, Kurashina, Kaihara and Mizoguchi to follow the IJCAI meeting in Tokyo. It was held on August 25, 1979, and was attended by over 100 biomedical researchers and clinical investigators. The workshop consisted of presentations by U.S. AIM researchers and Japanese investigators - two of them collaborators of the Resource.

Prior to the presentations, Drs. Kulikowski and Weiss gave demonstrations of the CASNET/Glaucoma and EXPERT/Rheumatology programs and Dr. Shortliffe demonstrated the MYCIN system. These were available for testing and study by the participants. In addition, Dr. Mizoguchi demonstrated the EXPERT/Glaucoma program that incorporates in its knowledge base a core of CASNET/Glaucoma and the new structures introduced by Dr. Kitazawa. The AIM-Japan Workshop had the effect of disseminating knowledge of AIM research among a large group of Japanese clinical investigators, and the attendance of a number of other IJCAI attendees lent an international character to the meeting.

3) IJCAI - International Joint Conference on Artificial Intelligence (Resource Participation):

Included among the other AIM activities that took place at the conference, Drs. Amarel and Mitchell chaired sessions, Drs. Kulikowski and Weiss presented two joint papers, and a third one was presented by our ophthalmology collaborators in Japan, Drs Kitazawa and Mizoguchi, who presented results of their experiments with the EXPERT knowledge-based methods. Drs. Kulikowski and Weiss demonstrated the CASNET/Glaucoma, EXPERT/Rheumatology and EXPERT/Thyroid consultation programs during the special demonstration periods at the conference. We connected by TYMNET via satellite to the Rutgers/LCSR DEC-20 and had excellent response time. This demonstrated the feasibility of remote collaborations and sharing of resources for the future. Dr. Mizoguchi demonstrated the EXPERT/Glaucoma program using Dr. Kitazawa's knowledge base, on the FUJIMIC DEC-20 in Tokyo, illustrating the practicality of knowledge base transfer methods.

4) National AIM Projects at Rutgers

The national AIM projects approved by the SUMEX-AIM executive committee were increased during the 1979 period of th Resource. A project using the BRIGHT system developed within the Resource and the NIH was continued in its application to various problems of clinical research by the group headed by Dr. W. Gordon Walker at the Johns Hopkins University and Hospital. We have projects that have their primary locus of activities on the SUMEX system and also use the Rutgers Resource for development, testing, and back-up functions. These include the MAINSAIL and CONGEN projects from Stanford University, and the INTERNIST project at the University of Pittsburgh. A project on medical knowledge representations at the Ohio State University was initiated on the Rutgers Resource Computer, as was a project in Artificial Intelligence models of clinical reasoning developed by Dr. R. Greenes at Harvard University. Dr. David Garfinkel at the University of Pennsylvania developed programs for his project on metabolic pathway modeling on the Resource Computer.

B) Critique of SUMEX-AIM Resource Management

We have now reached a steady state level of SUMEX-AIM usage--at least for the foreseeable future; we estimate it to remain at about 750 connect hours per year with an average compute to connect ratio of 1:25.

Since December 1979, the RUTGERS/LCSR computer is connected to the ARPANET again. Access to the ARPANET is facilitating close interactions between the Rutgers and Stanford AIM facilities, and in particular between the system staffs.

We continue to find the people support at SUMEX-AIM first rate and extremely helpful. On the technical side, we find communications via TYMNET of questionable reliability; and the SUMEX-AIM computer too heavily loaded.

III. RESEARCH PLANS

A) Project Goals and Plans

We are planning to continue along the main lines of research that we have established in the Resource to date. Our medical collaborations will continue with emphasis on development of consultation systems in rheumatology and ophthalmology. Work on belief systems and commonsense reasoning will continue with emphasis on the psychology of plan recognition and handling of stereotypes. Our core work will continue with emphasis on further development of the EXPERT framework and also on AI studies in representations and problems of knowledge and expertise acquisition. We also plan to continue our participation in AIM dissemination and training activities as well as our contribution--via the RUTGERS/LCSR computer--to the shared computing facilities of the national AIM network.

In October 1979 we submitted to NIH a renewal proposal for the Rutgers Resource. Our proposal for a five-year continuation (December 1, 1980 to November 30, 1985) was reviewed by a special study section earlier this April. A decision by NIH is expected in late May.

B) Justification and Requirements for Continued SUMEX USE

Continued access to SUMEX is needed for:

1) Backup for DEMOS, etc.

2) Programs developed to serve the National AIM Community should be runnable on both facilities.

3) There should be joint development activities between the staffs at Rutgers and Sumex in order to ensure portability, share the load, and provide a wider variety of inputs for developments.

C) Needs and Plans for other Computing Resources Beyond SUMEX-AIM

Beyond the current SUMEX-AIM facility there is need for access to a more 'personal' type computing facilities (e.g. PERQ, DORADO, LISP machines, etc.) In addition SUMEX might provide a high quality output device (e.g. line printer or XGP) for the community.

D. Recommendations for Future Community and Resource Development

Future development for hardware should be in the direction of smaller machines which could ultimately be acquired at or transferred to user's sites (e.g. VAXes or the larger personal computers). Special efforts in networking small machines and in developing methods of using small computers would be desirable. In particular, methods and technology for system transfer from large machine environments to small machines would be increasingly useful to the AIM community.

We continue to consider community developments as one of the significant goals of the national AIM project. The program of AIM Workshops should continue and new arrangements involving a program of lectures/seminars and working visits by AIM scientists should be encouraged.

9.2.9 Decision Models in Clinical Diagnosis [Rutgers-AIM]

A Goal-Oriented Model of Clinical Decision-Making Incorporating Decision Thresholds

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I. Summary of Research Program

A. Project Rationale

The major objective of this project is to increase understanding of the way in which probability of diagnosis, and costs and benefits of contemplated actions, interact in the selection of the most appropriate actions. Actions include therapeutic as well as diagnostic procedures. The initial problem area being considered is the management of a patient with upper abdominal pain. The decision problem is modeled as a goal-oriented search process, where actions available for selection represent the system's goals. Costs and benefits of the actions are incorporated in the heuristic device of a probability threshold, which must be exceeded for the action to be taken. Production rules, modified to incorporate evaluation of probabilities in relation to thresholds, are used to embody the decision conditions.

Top-level patient management goals usually require for their adoption that diagnostic thresholds be exceeded, which in turn require specific groups of diagnostic tests to be obtained. Selection of these tests may recursively require still other diagnostic thresholds to be exceeded, involving other preliminary diagnostic tests. A forward-chaining search strategy is used, which restricts consideration to diagnoses exceeding minimal "rule-out" thresholds. When a group of diagnostic tests is eligible to be done, based on the above search, its members are placed in an eligibility list. Concurrent search may find several eligible test groups. Selection among eligible tests is based on heuristics such as: greatest likelihood of enabling a higher level goal to be reached, highest number of goals to which the test relates, and least overall cost or risk.

At the initiation of a session, information already known about a patient is entered. This, together with the system's estimates of prevalence of the various diseases considered, is used to "prime" the differential diagnosis probability distribution by means of Bayes theorem. The system identifies a next test to perform. As results on tests become available and are entered into the system, Bayes theorem is again used to update the distribution.

B. Medical Relevance and Collaboration

This model is somewhat unique in its attempt to incorporate both the decision analytic view of costs and benefits, and heuristics which make the problem more tractable. A probability threshold may be viewed as the indifference point for a decision maker, where the relationship between cost and benefit is equal for any of the available options. It can thus be used as a device for collapsing and summarizing an entire distal decision tree.

By maintaining the differential diagnosis in probabilistic terms, rather than using various surrogates for probability, the model is able to relate diagnostic probability to action, through the translation provided by the threshold concept. This permits behavior of the model to be analyzed and tuned either in terms of the accuracy of its probability estimates or the suitability of thresholds. Further, we believe that the use of a "rule-out" threshold, to permit the model to focus on limited subsets of the possible diagnoses, bears a resemblance to the focusing process which medical problem solving actually exhibits.

This project involves internal collaboration between the Departments of Radiology and Medicine at Peter Bent Brigham Hospital, with consultation by the Department of Biostatistics at Harvard School of Public Health, Bolt Beranek and Newman, Inc., and the Office of Medical Education, Michigan State University.

C. Highlights of Research Progress

In this first year of effort, major tasks have involved: (1) development of prototype programs for acquisition of decision rules, construction of probability tables, output of rules and probability data, and execution of the decision-making system; and (2) elaboration of specific decision rules and probability estimates for the management of patients with upper abdominal pain. An operational prototype of each of the programs described above now exists. In the application to abdominal pain, we consider approximately 90 diagnostic entities, 40 management goals, and 60 individual tests. Thus far, we have concentrated on the subset of patients suspected of having gastrointestinal obstruction, involving 6 diagnostic entities. The rules and probabilities are derived subjectively by periodic sessions with a gastroenterologist, T. E. Bynum, M.D.

D. Relevant Publications

[1] Greenes RA: A goal-directed model for investigation of thresholds for medical action. Proc Sympos on Computer Applications in Medical Care, Washington, DC, October, 1979, IEEE, pp 47-51.

[2] Greenes RA, McNeil BJ: The use of statistical measures as an aid to selection of appropriate diagnostic procedures. Proc 65th Scientific Assembly, RSNA, Atlanta, GA, November, 1979, p 257 (abstract).

[3] Greenes RA: The diagnostic test order decision problem. Proc of the 6th Illinois Conf on Medical Information Systems, Champaign-Urbana, Il, April, 1980 (in press).

[4] Greenes RA: Medical decision-making research: the role of academic radiology. Third Int Sympos on the Planning of Radiological Departments. Amsterdam, Holland, June, 1980.

E. Funding Support

This project is part of a Program Project, "Investigations in Clinical Decision-Making", supported by the National Library of Medicine, grant NLM 1 P01 LM03401, Robert A. Greenes, M.D., principal investigator. Total award (7/1/79-6/30/84), $1,177,582. First year (7/1/79-6/30/80), $235,582.

II. Interactions with the SUMEX-AIM Resource

A. Medical Collaboration and Program Dissemination Via SUMEX

With this project only in its early stages, no significant medical collaboration or dissemination has yet occurred. Because of the specific features of our model, it was not considered to be readily implemented within the framework of other extant decision-making systems.

B. Sharing and Interactions with Other SUMEX-AIM Projects

The project utilizes the PDP-20 AIM resource at Rutgers University. In making the decision to utilize the Rutgers rather than the SUMEX facility, much assistance and documentation was provided by the technical directors of both facilities. Our choice of Rutgers was based primarily on the expectation that the response time and communication support through TYMNET for an east-coast user would be likely to be better.

We have participated in the site visit to the AIM resource at Rutgers in April, 1980, and will also be participating in the AIM Workshop, and Artificial Intelligence in Medicine Continuing Education Tutorial, at Stanford, in August, 1980.

C. Critique of Resource Management

We are most pleased by the personal interest shown, and assistance provided, by the technical directors of both AIM resources. We have had no serious problems with the use of the Rutgers facility.

III. Research Plans (8/80-7/86)

A. Project Goals

Near term goals involve (a) expansion of the decision rules and probability matrix to include the entire range of diagnostic entities considered in our model of upper abdominal pain, (b) incorporation of the time duration involved in diagnostic tests into the selection process, and

(c) evaluation of model performance. Initially, our criteria for evaluation will be agreement with an expert regarding the management goals selected, and the tests utilized.

Long-range goals include (a) refinement of the human interaction with the system, (b) the incorporation of capabilities for explaining its decisions, (c) evaluation of sensitivity of its conclusions to estimates of the various probabilities and thresholds, and (d) incorporation of empirical probability data into the model when available. Ultimately, we would like to evaluate its suitability as a consultant.

B. Justification and Requirements for Continued SUMEX Use

We expect the complexity of our programs to grow considerably during the next 2-3 years. The knowledge and data bases will grow also, and we anticipate moderately large storage requirements. Continued availability of the SUMEX-AIM resource is thus highly desirable in terms of our need for LISP programming capabilities.

In addition, we would hope that closer interaction with other AIM users in the evaluation of our model and other approaches will become possible, as we both familiarize ourselves with the characteristics of other systems, and further develop the capabilities of our system.

C. Needs and Plans for Other Computing Resources Beyond SUMEX-AIM.

This project has no present need for other computing resources, although some of the probability data incorporated into the model are derived from studies carried out on other computer systems.

D. Recommendations for Future Community and Resources Development

As microcomputers become increasingly powerful, inexpensive, and capable of supporting at least single-user LISP programs, we expect that a natural evolution toward such systems will occur. Efforts to ensure compatibility, portability, and the ability to interface such systems to the AIM network will, thus, be highly desirable.

9.2.10 Heuristic Decisions in Metabolic Modeling [Rutgers-AIM]

Heuristic Decisions in Metabolic Modeling

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I. SUMMARY OF RESEARCH PROGRAM

A. Project Rationale

This research is concerned with developing methods of constructing computer models of complex metabolic systems, and applying thereto artificial intelligence and other relevant computer science techniques.

B. Medical Relevance

Most of our work is concerned with modeling cardiac metabolism and the effects of ischemic heart disease. There has been some collaboration with appropriate cardiac physiologists and cardiologists. We are trying to extend our research to diabetes and hematology, in collaboration with experts in those particular fields.

C. Research Progress

We constructed cardiac metabolism models, emphasizing the effects of acidosis, fatty acid metabolism, and the glycogenolysis cascade; this work is still in progress. We have developed methods for sensitivity analysis and a new program for building these models. Current efforts emphasize completing the glycogenolysis model, correcting some of the existing models, designing relevant experiments, and writing up a mass of completed models. We are extending our model-building software, and making it "friendly" enough for unsophisticated users.

D. List of Relevant Publications

M.J. Achs and D. Garfinkel, Metabolism of the Acutely Ischemic Dog Heart. I. Construction of a Computer Model. Am. J. Physiol. 236, R21-R30 (1979).

D. Garfinkel and M.J. Achs, Metabolism of the Acutely Ischemic Dog Heart. II. Interpretation of a Model. Am. J. Physiol. 236, R31-R39 (1979).

D. Garfinkel, M.J. Achs, M.C. Kohn, and L.S. Menten, Modeling of Complex Metabolic Systems as a Composite of Standard Computer Science Techniques, Proceedings of Summer Computer Simulation conference, 1979.

L. Garfinkel, M.C. Kohn, and D. Garfinkel, Computer Simulation of the Fructose Bisphosphatase-Phosphofructokinase Couple in Rat Liver, Eur. J. Biochem. 96, 183-192 (1979).

M.C. Kohn, L.E. Menten, ad D. Garfinkel, A Convenient Computer Program for Fitting Enzymatic Rate Laws to Steady-State Data, Comput. Biomed. Res. 12, 461-469 (1979).

M.C. Kohn, M.J. Achs and D. Garfinkel, Computer Simulation of Metabolism in the Pyruvate-Perfused Rat Heart. I. Model Construction. Am. J. Physiol. 237, R153-158 (1979).

L.E. Menten, M.C. Kohn and D. Garfinkel, A Convenient Computer Program for Estimation of Enzyme and Metabolite Concentrations in Multienzyme Systems (in progress).

E. Funding Support

1.) "Computer Simulation in Cardiology" HL 15622, 3 years, Dec. 1, 1977-Nov. 30, 1980; current year $111,051. Competing renewal now pending, $162,744; $181.060; $199,548; $220,647 (for four years).

2.) "Computer Modeling Methods for Metabolic Systems," (GM 16501-11A1), $60,598; $63,860 (two years) April 1, 1980 - March 31, 1982.

3.) "Computer-Aided Study of Glycolysis in Pancreatic Islets," submitted to NIH as a part of the Diabetes Center renewal proposal. Direct costs $38,853; $41,652; $44,322 for 3 years.

4.) "Metabolism of Malarial, Aged, and Normal Erythrocytes" (including experimental subcontract) submitted to NIH, $144,283; $158,267; $169,609 (3 years).

II. Interactions with the SUMEX-AIM Resource

There has been no interaction with SUMEX directly, and none is anticipated. There has been considerable interaction with the Rutgers resource, especially in the form of a personal collaboration with Prof. Kulikowski, and moderate usage of their computer. The program we have developed and are writing up was developed there. I have also been a regular attendant at AIM workshops over the last few years, and have made valuable contacts and acquired an understanding of the field that would not have been possible otherwise. Overall, interactions through the Rutgers resource have been of considerable importance to our development.

III. Research Plans

We are now at the stage where our technique research is concerned with knowledge representation and acquisition, with intelligent (and fuzzy) data bases having some of the characteristics of a knowledge base, with representation of knowledge in our subject area of interest, and with overcoming incompleteness. We cannot realistically expect much help in these matters from the subject-matter experts, and need the help of the AI community. We expect to continue using the Rutgers machine. Within the next year and a half we will try to refine our existing program and other model-building methods, to make them more manageable, modularized, efficient, and faster, and also friendly enough to be operated by biological experts directly without too much help from programmers or professional simulationists. We will also devise methods (using symbolic manipulation) to break large complex models down into workably small pieces. In the next few months we hope to start attacking the data-base (and later knowledge-base) aspects of this work.

Long-range research goals will be critically dependent on other funding, so we cannot give details now. We hope to be able to build a good model of cardiac ischemia which can be used to make predictions, to design experiments for areas in metabolism (especially multi-enzyme systems) which are now inefficient. This modeling process must be fast enough to be of use and rigorous enough to be reliable. This implies development of the techniques mentioned above to the point where they can do most of the necessary work.

We do not expect to use the SUMEX computer, but do expect to make considerable use of the Rutgers computer and the expertise of the department, since such expertise is not otherwise available to us. It is conceivable that several years from now we may want to link in a personal computer under the collaborative linkage described in the RENEWAL RATIONALE, but this is sufficiently far in the future that a justification for one cannot be given at the present time.

9.3 Pilot Stanford Projects

The following are descriptions of the informal pilot projects currently using the Stanford portion of the SUMEX-AIM resource pending funding, and full review and authorization.

9.3.1 Ultrasonic Imaging Project

Ultrasonic Imaging Project

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I. Summary of Research Program

A. Project Rationale

The long range goal of this project is the development of an ultrasonic imaging and display system for three-dimensional modeling of body organs. The models will be used for non-invasive study of anatomic structure and shape as well as for calculation of accurate organ volumes for use in clinical diagnosis. Initially, the system will be used to determine fetal volume as an indicator of fetal weight; later it will be adapted to measure left ventricular volume, or liver and kidney volume.

The general method we plan to use is the reconstruction of an organ from a series of ultrasonic cross-sections taken in an arbitrary fashion. A real-time ultrasonic scanner will be coupled to a three-dimensional acoustic position locating system so that the three-dimensional orientation of the scan plane is known at all times. During the patient exam a dedicated microcomputer based data acquisition system will be used to record a series of scans over the organ being modelled. The scans will be recorded on a video disk which is controllable by the microcomputer. 3D position information will be stored on a floppy disk file. The microprocessor will then be connected to SUMEX where it will become a slave to an AI program running on SUMEX. The SUMEX program will use a model appropriate for the organ which will form the basis of an initial hypothesis about the shape of the organ. This hypothesis will be refined at first by asking the user relevant clinical questions such as (for the fetus) the gestational age, the lie of the fetus in the abdomen and complicating medical factors. This kind of information is the same as that used by the clinician before he even places the scan head on the patient. The model will then be used to request those scans from the video disk which have the best chance of giving useful information. Heuristics based on the protocols used by clinicians during an exam will be incorporated since clinicians tend to collect scans in a manner which gives the most information about the organ. For each requested scan a prototype outline derived from the model will be sent to the microcomputer. The requested scan will be retrieved from the video disk, digitized into a frame buffer, and the prototype used to direct a border recognition process that will determine the organ outline on the scan. The resulting outline will be sent to SUMEX where it will be used to update the model. The scan requesting process will then be continued until it is judged that enough information has been collected. The final model will then be used to determine volume and other quantitative parameters, and will be displayed in three dimensions.

We believe that this hypothesize verify method is similar to that used by clinicians when they perform an ultrasound exam. An initial model, based on clinical evidence and past experience, is present in the clinician's mind even before he begins the exam. During the exam this model is updated by collecting scans in a very specific manner which is known to provide the maximum amount of information. By building an ultrasound imaging system which closely resembles the way a physician thinks we hope to not only provide a useful diagnostic tool but also to explore very fundamental questions about the way people see.

We plan to develop this system in phases, starting with an earlier version developed at the University of Washington. During the first phase the previous system will be adapted and extended to run in the SUMEX environment. A clinical study will then be carried out to determine its effectiveness in predicting fetal weight. At the same time computer vision techniques will be used to develop the system further in the direction of increased applicability and ease of use. We thus hope to develop a limited system in order to demonstrate the feasibility of the technique, and then to gradually extend it with more complex computer processing techniques, to the point where it becomes a useful clinical tool.

B. Medical relevance

This project is being developed in collaboration with the Ultrasound Division of the Department of Obstetrics at Stanford, of which W.D. McCallum is the head.

Fetal weight is known to be a strong indicator of fetal well-being: small babies generally do more poorly than larger ones. In addition, the rate of growth is an important indicator: fetuses which are "small-for-dates" tend to have higher morbidity and mortality. It is thought that these small-for-dates fetuses may be suffering from placental insufficiency, so that if the diagnosis could be made soon enough early delivery might prevent some of the complications. In addition such growth curves would aid in understanding the normal physiology of the fetus. Several attempts have been made to use ultrasound for predicting fetal weight since ultrasound is painless, noninvasive, and apparently risk-free. These techniques generally use one or two measurements such as abdominal circumference or biparietal diameter in a multiple regression against weight. We recently studied several of these methods and concluded that the most accurate were about +/-200 gms/kg, which is not accurate enough for adequate growth curves (the fetus grows about 200 gms/week). The method we are proposing is based on the assumption that fetal weight is directly related to volume since the density of fetal tissue is nearly constant. We are hoping that by utilizing three dimensional information more accurate volumes and hence weights can be obtained.

In addition to its use in predicting fetal weight, this system could be used to determine other organ volumes such as that of the left ventricle. Left ventricular volumes are routinely obtained by means of cardiac catheterization in order to help characterize left ventricular function. Attempts to determine ventricular volume using one or two dimensional information from ultrasound has not as yet demonstrated the accuracy of angiography. Therefore, three-dimensional information should provide a more accurate means of non-invasively assessing the state of the left ventricle.

C. Highlights of Research Progress

During the past year we have essentially completed the first phase of this project which was to implement and adapt the previous system to the SUMEX environment. The accomplishments related to that goal are:

1. Completion of a microprocessor based data acquisition system

The following hardware has been obtained and integrated into the system--

a) A Toshiba real-time ultrasonic phased array scanner, in routine clinical use at the Dept. of Obstetrics.

b) A Sony video tape recorder and Hitachi monitor, for use in recording the scans prior to their being outlined with the light pen.

c) A custom built acoustic position locating system for determining the position of the scan plane in space, supplied to us by W.E. Moritz at the University of Washington.

d) A Datamedia computer terminal for communicating with SUMEX and controlling the procedure.

e) A microprocessor-based video graphics system supplied to us by Varian Corporation. This system includes a light pen, dual floppy disks and video display memory.

A large amount of software for the data acquisition system has been written and is now working. This software consists of routines to direct the patient exam, during which time scans are recorded on video tape and position information is stored on floppy disk. Additional software directs that the scans be outlined with the light pen (not digitized in this first phase) and stored with the position information. Finally, a program has been written which converts the microprocessor into a video graphics terminal. Characters are passed back on forth as with an ordinary terminal but special command sequences cause graphics to be displayed and a file transfer to take place. The file transfer, called File Transfer to Micro, is packet oriented and should prove useful to anyone wanting to do file transfers between SUMEX and a microcomputer. It is also flexible enough so that it can form the basis of a system for sending commands from SUMEX to do local image processing functions.

2. Completion of SUMEX high level routines

The SUMEX software for this first phase includes procedures to transfer the data from floppy disk to SUMEX (via the file transfer protocol), to build a 3D reconstruction using simple interpolation, and to display the images on a graphics terminal.

3. Initial tests and first patients

The completed first phase system has been used to build 3D displays of simple models such as cylinders in a water tank. We have also tried it on 2 patients and have obtained 3D plots of the fetal head and trunk and of the placenta inside the uterus.

The research currently in progress relates to testing the system:

1. An engineering study is being carried out on cylinders, balloons and point targets to determine the bench accuracy of the system.

2. A clinical protocol is being established on several obstetrics patients. Once we have gained enough experience we will begin our clinical study to determine the ability of the method to predict fetal volume and weight.

D. Publications

Brinkley, J.F., Moritz, W.E., Baker, D.W., "Ultrasonic Three-Dimensional Imaging and Volume From a Series of Arbitrary Sector Scans", Ultrasound in Medicine and Biology, vol 4, pp 317-327.

Brinkley, J.F., McCallum, W.D., Daigle, R.E., "A Distributed Computer System for Fetal Weight Determination", Proceedings of the 24th Annual Meeting of the American Institute of Ultrasound in Medicine, Montreal, August 27-31, 1979, p 113.

McCallum, W.D., Brinkley, J.F., "Estimation of Fetal Weight from Ultrasonic Measurements", American Journal of Obstetrics and Gynecology, 133:2, pp.195-200, Jan. 1979.

E. Funding status

"Ultrasonic Measurement of Fetal Volume and Weight"
Principal Investigator: W.D. McCallum, M.D.
Assistant Professor
Department of Obstetrics and Gynecology
Stanford University
Funding agency: National Institute of Child Health and Human Development
Number: 1-R01 HD12327-01
Total term and direct cost: 7/1/79-6/30/81, $111,823
Current funding period: 7/1/79-6/30/80, $60,423

II. Interactions with SUMEX-AIM resource

A. Collaborations

We are collaborating more with medical people than anyone else. The project is located in the Obstetrics Department at Stanford where W.D. McCallum manages the ultrasound patients. We have also been discussing the the applicability of the current system to the heart with Dr. Richard Popp in the Division of Cardiology at Stanford.

B. Sharing and Interactions with SUMEX projects

Mostly personal contacts with the Heuristic Programming Project and MYCIN project at Stanford. The message facilities of SUMEX have been especially useful for maintaining these contacts. Since the first phase of the project is now essentially completed we expect to interact much more with other SUMEX projects in order to develop the AI ideas.

C. Resource management

In general SUMEX has been a very usable system, and the staff has been very helpful. The only complaint is that it is impossible to get anything done in the afternoons since we always get bumped.

III. Research Plans

A. Project goals and plans

As mentioned in Part I we plan to implement this system in phases, each phase requiring use of more sophisticated artificial intelligence techniques. The major phases are as follows (in chronological order:

1. Set up prototype system and test its ability to predict fetal weight.

This system has been developed and is now undergoing testing. We plan to carry out engineering and clinical studies in order to test the ability of the current system to predict fetal and cardiac volume. If successful the system may have clinical impact as it stands. However, our initial patient studies have demonstrated the basic limitations of the system, which are inadequate models and difficulty of use. From a medical point of view the next phases will be attempts to remove these limitations.

2. Explore other methods for geometric modelling, AI techniques of goal directed problem solving.

In order to develop adequate models and control strategy it will be necessary to examine other AI methods of generating models and using them to guide problem solving programs. For this aspect of our research the SUMEX-AIM community should be especially useful.

3. Develop program, as outlined in the introduction, with several limitations--

Only a simple organ will be modelled at first, i.e. not the entire fetus including limbs the computer will still request certain scans to be retrieved from the video disk but the operator will outline them with the light pen. Since ultrasound image quality is improving so rapidly it makes sense to wait as long as possible before attempting automated border recognition. The models and control strategies developed during this phase should be useful when actual border recognition is attempted however.

4. Extend the technique to more irregular objects structured models will be developed so that the fetal limbs can be included.

5. Add image processing hardware, develop automated border recognition software.

The models developed in the last two phases will be used to guide the border recognition process.

As these phases are implemented they will continue to be tested against the clinical data acquired and stored on floppy disk by the data acquisition system. In this way we can develop new ideas while continually upgrading the clinical utility of the system.

B. Justification for continued use of SUMEX

The goals of this project seem to be compatible with the general goals of SUMEX, ie to develop the uses of artificial intelligence in medicine. The problem of three-dimensional modelling is a very general one which is probably at the very heart of our ability to see. By developing a medical imaging system that models the way clinicians approach a patient we should not only develop a useful clinical tool but also explore some very fundamental problems in AI.

C. Need for resources

1.SUMEX resources

The only additional requirements we have at present are for an additional file directory and for a little more time in the afternoon. At present we only have one directory which must be shared by the system developer and an additional person conducting the engineering and clinical studies. An additional directory could be designated for users of the current implementation of the system while the present directory could be used for new developments.

2. Other resources

Judging from our present experience it appears that SUMEX could not handle the amount of data required for image processing on digitized ultrasound scans. This is one of the main reasons we are proposing a distributed system in which SUMEX only directs a smaller machine to do the actual number crunching. It is also one of the reasons we are postponing direct digitization until later. As microprocessors become more powerful they will be capable of acting as slaves to an intelligent SUMEX program. The AI program will direct the image processing functions of the micro so that the data is processed in an intelligent way, but SUMEX will only see the results of that processing, not the actual data. We will thus need to keep track of developments in microcomputers so that we can develop this kind of distributed system.

3. Recommendations

Since we are planning to develop a distributed system we would hope to see these kind of systems being developed by the SUMEX resource. Projects that would be of direct interest are networks (such as ETHERNET), personal computer stations, graphics displays, etc.

9.4 Pilot AIM Projects

The following are descriptions of the informal pilot projects currently using the AIM portion of the SUMEX-AIM resource or the Rutgers-AIM resource pending funding, and full review and authorization.

9.4.1 Coagulation Expert Project

Coagulation Expert Project

Donald Lindberg, M.D.
University of Missouri
Columbia, Missouri

I. SUMMARY OF RESEARCH PROGRAM

A. Project rationale

Preliminary experiment in attempting to form a clinical consultant program based on a formal representation of medical knowledge of the blood coagulation (or clotting) expert.

B. Medical relevance and collaboration

Experts in clotting are few and tend to be based at University hospitals or large tertiary care facilities. It would be extremely helpful if this knowledge could be made available to physicians via an automated system.

Relevance of such a proposed system would be with respect to diagnosis, management, and continuing medical education.

The team at the University of Missouri-Columbia consists of the following individuals:

Lamont Gaston, M.D.
David Goldman
Lawrence C. Kingsland III
Donald A. B. Lindberg, M.D.
Haruki Ueno, Ph.D.
Anthony Vanker. Ph.D.

Dr. Gaston is a consulting hematologist, director of a coagulation laboratory, and co-director of a blood-banking service.

Expertise in the field as well as clinical laboratory and patient records are being provided by UMC to build and test the consultant. In the future we plan to incorporate the views of external experts as well.

A formal research proposal to NIH is planned for fall, 1980, based on the studies performed on SUMEX.

C. Highlights

-Accomplishments

Use of UNITS/AGE: an initial model has been created on SUMEX.

Experimental use of EMYCIN: a feasibility test with a text book level consultant model has been created on SUMEX.

Use of local LSI-11: in addition, the initial knowledge base has been assembled into a simpler (but operational) system on a DEC LSI-11 using RT-11 and BASIC.

We have selected a strategy for development. This is to begin with the interpretation of clinical laboratory tests: first the full coagulation screen (of 6 tests), then the partial coagulation screen (of 3 tests), and finally the individual determinations. In all these cases, laboratory and clinical features will be taken into account.

-Research in progress

Currently we are testing the initial models against actual clinical records for 270 patients. This is partly as a validation of the work done, and partly as a means to bring to our attention the unusual circumstances and unforeseen problems which we know will be present. That is, we have allowed for all feasible patterns of results, but (probably) have not yet allowed for all the surrounding clinical circumstances. In any event, the data gathering is almost complete and testing is about to begin.

D. List of relevant publications

None

E. Funding support

This preliminary research phase is being supported from two sources:

1. USPHS Grant No. T15 LM 07006, "Training Program in Medical Information Science". Full funding is $162,410/year. About $25,000/year is being devoted to this project.

2. USPHS Grant No. HS 02569, "Health Care Technology Center." Current funding is $500,000/year. About $12,000/year is being devoted to this project.

II. <u>INTERACTIONS WITH THE SUMEX-AIM RESOURCE</u>

A. Medical collaborations and program disseminations via SUMEX

Dr. Vanker will give an oral presentation of our work at the Spring Meeting of Trainees and Directors, N.L.M. Training Programs, in May at Columbus, Ohio. He also plans to demonstrate our AGE-implemented model during the meeting. We have also given individual demonstrations of our models to visiting scientists (including some from Japan) at UMC.

B. Sharing and interactions with other SUMEX-AIM projects

In February, 1980, David Goldman, a medical student at UMC and former pre-doctoral fellow in the Information Science Group, spent a week at

Stanford University becoming acquainted with the various artificial intelligence (AI) systems in development at SUMEX. In fact, with the help of members of the SUMEX-AIM community, he was to implement a simple, workable coagulation model in EMYCIN.

In March, 1980, Dr. Ueno attended a workshop on AGE at Stanford. Through this workshop he was able to learn a great deal that was directly applicable to our work. He also obtained a better understanding of the UNITS package and how it might be used to interface with AGE. All of in the study group are planning to attend the AIM-tutorial at Stanford in August, 1980.

Since the AI systems in which we are interested are in some stage of development on the SUMEX computer, and since partial documentation does exist, we have been able to learn a great deal on our own by an interactive, trial-and-error method.

Of course we have had many questions, and we have received prompt and helpful information from various members of the SUMEX-AIM community via the network electronic message system.

C. Critique of resource management

We have found the people at SUMEX to be uniformly helpful and more than willing to aid us in our attempts to understand the various aspects of AI in medicine. Both Mr. Goldman and Dr. Ueno were delighted with their experiences at Stanford, and commented on the willingness of otherwise very busy people to help them with their problems.

One of the drawbacks of SUMEX is that quite often the interaction is slow. There have been days when we must wait up to several minutes between exchanges between our terminal and SUMEX. This is apparently due to a high average load on SUMEX at the time. We have had no other problems with the resources at SUMEX and we feel the management has done a good job thus far.

III. RESEARCH PLANS

A. Plans for Summer, 1980

1. Continue assembling the knowledge data base, with emphasis on documentation of the primary literature sources for the knowledge sources (KS).

2. Continue learning the various aspects of UNITS/AGE and EMYCIN.

3. Continue comparing the two potentially complex models with the inherently simpler microprocessor version.

4. Appoint a clinical test panel for consultation on development of the next features.

5. Prepare the application to NIH.