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International Institute
for
Applied Systems Analysis

PROCEEDINGS OF IIASA PLANNING CONFERENCE ON COMPUTER SYSTEMS

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The views expressed are those of the contributors and not necessarily those of the Institute.

The Institute assumes full responsibility for minor editorial changes made in grammar, syntax, or wording, and trusts that these modifications have not abused the sense of the writers' ideas.

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Minutes of the Research Planning Conference on Computer Systems*

First Day

Preliminaries

Mr. Raiffa, the Director of IIASA, welcomed delegates to the seventh in a series of conferences designed to generate ideas of assistance in planning a meaningful, integrated research strategy for the Institute. He encouraged everyone to resist the inhibiting force of formality and to ventilate his thoughts freely. The purpose of the conference was not to formulate policy but accumulate suggestions. IIASA was characterized as research-oriented, concerned with methodological questions and concrete applied problems, and not to be confused with a consulting firm. Precisely because institutes and committees, not governments, are members of IIASA, the Institute, not burdened with any official obligations, is in a unique position to pursue objective research. Support by prestigious member organizations kindles lofty intellectual aspirations. Into whatever various disciplines IIASA's interests may delve, all vision will remain tinged with concern for management and issues of control.

Mr. Raiffa proceeded to explain how IIASA's identity and structure qualified the Institute to render valuable service in many instances as a "sophisticated clearinghouse," a place to find out who was doing what, where, of importance. IIASA at the same time would engage in projects of its own and was at present readying a menu of alternative activities to present to its Council. IIASA did not contemplate concentrating efforts on two or three specific and yet vast projects, rather it would tackle a considerable variety of interrelated problems. In-house scientists (a total of ninety projected for 1975) would provide liaison with scientists in member institutes involved in relevant ongoing research. Indeed, there was considerable evidence to suggest the preparedness of numerous non-member organizations and agencies, indeed their willingness, to collaborate with IIASA. Mr. Raiffa emphasized the importance of cooperation on a grand scale to all of IIASA's plans, not only in terms of manpower but machine power as well. He urged delegates not to have limited ideas of IIASA's potential derived from the size of its budget or modest dimension of its staff, but to realize how extensive a network of resources IIASA was in an advantageous position to tap. In proposing areas of interest for IIASA, they should remain conscious of exploiting opportunities for cooperation. Pro-

*These minutes were prepared by D. Bloch.

posed activities must be feasible; their importance must be of the first magnitude. Topics should be either of global significance, overriding national frontiers, or of universal significance, recurring in similar guise within national boundaries everywhere. Efficiency and alacrity should characterize IIASA's attack on problems. The Institute has no desire to repeat work done elsewhere.

The Director described IIASA's hopes for building superior scientific supporting services. He sketched the present state of IIASA's computer division, emphasizing that maximum flexibility is at present a dominant desideratum, and that no irreversible decisions had yet been taken. He told the conference that IIASA was currently doing test runs to determine what mini-computer available on the market might best satisfy increasing needs. He expressed optimism about the possibility of hooking up at the beginning of the coming year to a major computer in Vienna, the Cyber 73-74.

Mr. Glushkov, co-chairman of the conference, urged the delegates to concentrate upon two different basic questions: 1) what should be the role of computers in servicing other IIASA projects, and 2) what are discrete projects of interest within the computer field.

Mr. Capriz, the other conference co-chairman, wished to impress upon all the provisional nature of the agenda. He read aloud from the IIASA brochure of background information (6.7, 6.9) to suggest the possible range of discussion. The few days of meetings were a rare opportunity to indulge in fantasy and to think boldly. No idea would be out of order. Computers could be discussed not only as a science or service, but also as a phenomenon.

Presentation of Research Developments in Computer Science in National Member Countries of IIASA

Abashed to attempt any thorough delineation of developments within the field of computer science in their respective countries, delegates ventured "with apologies" to express "unrehearsed" views, and offered "personally biased" accounts. Some cited particular programs and scientists. Others attempted to designate trends and primary concerns. Still others limited their reports to matters which they believed of especial relevance to IIASA. Wherever possible, Mr. Raiffa informed the conference of pertinent IIASA activity in other fields.

German Democratic Republic (Mr. Lehmann)

Research developments concerning problem-oriented languages are of foremost importance to IIASA, for efficient utilization of information processing of such tools. Mr. Lehmann specified a number of special languages developed and implemented in the GDR.

United Kingdom (Mr. Longuet-Higgins)

Computers are now prominent in industry, in university communities, and in government agencies. A general application of particular importance and fraught with problems is that of bibliographic retrieval: the keeping of records, the indexing and ordering of an extensive body of literature. There is presently concern for the compatibility of equipment internationally--an issue under discussion recently when personnel from various national meteorological offices conferred. Government research laboratories are now engaged in scheduling problems related to road control and the regulation of traffic. The treasury indulges in economic forecasting.

United States (Mr. McCarthy)

The Computer Science Department of Stanford University has formulated requisites for an adequate time-shared computer service identified on the basis of its experience. These are:

a) individual terminals in a scientist's own office;

b) silent display terminals rather than noisy printing terminals;

c) facilities for composing documents (including upper and lower case characters and skilled editors);

d) ample file space per person;

e) access to large memory programs on fast machines;

f) continuous availability on a 24-hour day basis, and

g) good languages, maximum compatability with other systems.

Mr. McCarthy discussed the advantages of computer networking, especially the capacity to access distant files with rapid transfer of programs and of documents and to run these programs on the home machines of their developers. Given IIASA's goal of constant cooperation, networking is a plausible solution. The success of the ARPA network was cited. He strongly supported the PDP 10, with the reservation that PDP 10 software is highly machine-specific, although adaptions are possible. (Mr. Raiffa mentioned that IIASA's thinking on the subject has been predominantly along the lines of such a time-sharing system. The prospect of relying solely on out-of-house computers, becomes less attractive when the proven fallibility of phone-line connections between Laxenburg and Vienna is considered.)

Canada (Mr. Borden)

The Michigan Terminal System is particularly suited to a computer system designed for applied systems analysis. It is useful for resource management problems. Models can be operated as pedagogical tools, instructing managers about structures. The Michigan Terminal System is especially attractive because users can function within the familiar territory of their chosen scientific disciplines without total immersion in computer sciences. (IIASA's ecological program is designated to involve managers in model processes, bringing modellers and decision makers into close contact.)

Federal Republic of Germany (Mr. Bauer)

Government programs engaged in computer research and application establish certain prerequisites of would-be participants. Two special research units in Munich are possibly of interest to IIASA: # 49, Computer Sciences; # 50, Cybernetics.

Canada (Mr. Florian)

IIASA should allow modelling work to generate problems in system analysis within computer sciences. Such problems infallibly arise. Study of public transportation in Canadian cities for example, inspired intense concern for how to handle large networks with computers. (Transportation is a conceivable topic of interest for IIASA's Urban and Regional Development project, pursuit of which would enmesh scholars in software compatability woes. IIASA might canvas the world for extant examples of the art of "network programming.")

France (Mr. Cadiou)

Two perspectives are possible: How can applied systems analysis help computer sciences? How can computer sciences serve applied systems analysis? ASA can provide methodology for evaluating computers, attempting to apply control theory methods to modelling of computer systems and to organization of computer networks. IIASA can provide independent advice to parties planning computer facilities for various purposes. On the other hand, computer science can refine numerical packages of value to ASA, can labor to perfect information retrieval systems on a broad data base, can improve relevant modelling and simulation technology. Furthermore, "Analysis of Algorithms" is currently proving useful to Operations Research.

Canada (Mr. Hatton)

IIASA must not blind itself to the fact that many problems of computer systems involve federal governments. Not all dilemmas are technical or organizational, but rather a striking proportion of significant difficulties are political and economic.

Austria (Mr. Trappl)

Personally enthusiastic about time-sharing, he expressed a mild lament that his own country imports all its hardware.

Austria (Mr. Sint)

An international group, LINK, is trying to join single nation models together functionally. Elsewhere, important research ongoing concerns a program capable of itself determining how much data is available relevant to a given problem and of proceeding to choose an appropriate mechanism for further investigation of the topic.

Austria (Mr. Firneis)

Mr. Firneis listed briefly institutions and groups engaged in research in the fields of computer sciences and artificial intelligence.

Italy (Mr. Capriz)

Computer research carried out in centers established by the Italian National Council of Research--usually as a cooperative venture with a university. Prominent areas of interest include the study of languages, and hydrology. Italy is involved in a project to achieve a European computer network proposed initially by the EEC and influenced by the Club of Rome.

Bulgaria (Mr. Dobrev)

Hazards of a library system which depends on collaboration of geographically scattered sources were depicted. Sadly, the experience of sending off a telex and receiving less than a rush response referring the sender elsewhere is not rare. A second cable may initiate the cycle again. In the end result comes frequently as a lottery between ten times the relevant information or nothing. Most work on computer systems is confined in Bulgaria to minicomputers. Work now is investigating traffic congestion and acquiring a social information system adequate to facilitate optimal distribution of working power in the land. Work is understood as an elemental part of an integrated system. Satisfaction was expressed that IIASA conceives of making available different sorts of computer facilities for different objectives.

Soviet Union (Mr. Aven)

Currently there is an intense investment of time, energy, and funds in the design and application of computers for control of branches of industry. Metal production is a prime example. Six hundred producers turn out 350,000 varieties of products weighing 100 million tons a year for 100,000 major users. Planning is thus an ambitious undertaking. The delegates expressed their interest in the nature of information processed. How much data? How precise? How organized? Mr. Aven explained that the "more or less optimal" solution arrived at involved more than a single center to process information. A wide variety of data is sought and new information is constantly fed into the system.

A second example of computer use in industry was to coordinate movements of a merchant marine fleet of approximately seventeen hundred ships. Optimal distribution of resources is again of essential importance. Man-machine issues are involved. Mr. Aven made it clear that planning in the metal industries and merchant marine fleet was integrated. The complexity of inter-relationships constitutes a typical "migraine headache" of systems analysis. A general system to control the national economy is being developed. (Mr. Raiffa alerted the conference that the following week a conference on Automated Control of Industrial Systems would investigate not only integration of isolated industries but the functioning of national economies as well.)

The question was raised whether any such inclusive general system within the territorial boundaries of a single nation is realistic? Where ores come from and where ships navigate create operational problems across borders. Should IIASA perhaps promote research into how models functioning within countries interact with each other?

Mr. Aven concluded his presentation with reference to Intourist's current computerization of its services in conjunction with various international travel agencies.

Soviet Union (Mr. Glushkov)

Considerable effort has been expended on computer languages. A grim practical reality the conference should keep in mind is how many programs at present are being implemented on hardware that cannot revise. (The issue of updating systems and revising models is of fundamental interest to the Automated Control of Industrial Systems conference.)

Japan (Mr. Nishino)

IIASA must derive a research strategy fully consistent with thoughtful consideration of international common interests. A prerequisite for addressing problems concerning resources, environment, and society is the preparation and management of a comprehensive data base at the disposal of versatile computer systems. Mutual assistance--actual effort, not simply the declaration of intent--is essential to the solution of any global problems. So long as nations cavalierly pursue independent policies, intelligent worldwide management cannot materialize. The potential of computer science and technology concerning large scale information and control systems for improving communication and achieving sound strategies for collaboration is inestimable. IIASA should concentrate on areas where the study of data base compilation and use is in its infancy, explore ideas not yet shackled into industry, and bypass problems where the computer industry is currently locked in competition. IIASA should carefully maintain working relations with various international organizations also concerned with similar problems. In pursuit of the establishment of a substantial welfare society, IIASA should dedicate itself to the improvement of man-machine communication and to the understanding of human intelligence through the use of extremely sophisticated information processing techniques.

Poland (J. Kulikowski and R. Kulikowski)

Most talented computer people presently work in international organizations. Research is concentrated in the Polish Academy of Sciences: The Institute of Applied Cybernetics is devoted to systems analysis, the Computational Center to computer sciences. A development plan exists to coordinate efforts in various universities. Intensive work is being done on operational theory and graph theory. An acute practical problem which scientists concerned with computer systems in Poland are facing is the choice of hardware suitable for major government projects entailing large information systems. Graphical and acoustical inputs are in use for the resolution of managerial problems. Good groups are actively confronting problems of computation and aspiring to a mathematical description of the computer itself. A noticeable tendency exists towards automating experiments and design. The opinion was expressed that the availability of the different kinds of computers as IIASA envisages may prove a mixed blessing. Now is the time to begin consideration of consequent communication difficulties.

<u>Hungary</u> (Non-member nation. Presentation by Mr. Sandori)

Projects of pressing interest involve the implementation of higher languages. Technologists are striving to break from the confinement of binary addition. The systems problem of how to distribute computer power optimally is also under study.

Mr. Glushkov and Mr. Capriz thanked the delegates for their presentations. Were the computer industry itself less competitive, there would no doubt be additional information available pertinent to computer systems research. Those attending the conference were requested to communicate with IIASA in writing as the continuing discussion jarred loose memories about additional individuals, groups, institutes engaged in projects relevant to IIASA's interests. In isolation, the Institute is essentially impotent.

<u>Presentation by Mr. Glushkov of Comments on the Research Theme: "Investigation of Methods of Forecasting Computer Facilities and Data Processing Systems Development" (Document J)</u>

Mr. Glushkov spoke about ongoing research in the field of forecasting at Institute of Cybernetics of the Ukrainian Academy of Sciences and possible applications in the field of computer technology. Dissatisfaction with previous approaches arose principally from the fact that forecasts formulated to span lengthy periods of time had to remain fixed as if carved in rock. A special feature of the present methodology is that it provides for continually revisable opinions combining a maximum number of experts proferring independent views both about the nature of essential intermediate stages in technological advance and about the likelihood of these stages being realized. Present research is being implemented on two computers and involves several thousands of experts giving opinions about twenty to thirty thousand various events. Mr. Glushkov accompanied his talk with a diagram illustrating procedures for breaking down the final forecast into a hierarchy of assorted sub-events.

The question was raised whether the described research program was interested in assessing probabilities in a technical world or in possibilities of achieving technological advance in a real world? Both, Mr. Glushkov replied. A delegate maintained that IIASA at heart was concerned with decision making, and that wherever capital formulation is a problem, decision making determines the speed of achieving potential. Forecasting in an ideal environment was of limited significance for the Institute.

Further discussion revolved around the difficulty of dealing with the dependency of precedent events in any forecasting enterprise. Are other experts requisite to determine the degree of independence? Some participants stated that Delphi techniques originally developed by the Rand Corporation and resembling those outlined by Mr. Glushkov in essential detail have had strictly limited success.

Mr. Raiffa asserted that the methodology of forecasting was of especial interest to IIASA. It arises as a problematical process in connection with numerous applied topics. It is a general case of the problem of optimization with multiple and conflicting goals. Indeed, at present in IIASA's Energy Project technological forecasting is essential to the problem of assessing risks involved in breeder reactors and thermal pollution. Decisions about monitoring depend upon penetrating the opacity of the future. Mr. Raiffa recalled his experiences at Dupont where corporate management sorely desired a reliable, probabilistic reporting system on key events leading to the production of target items in over seventy different projects. Problems of structuring events and working out their interdependency destroyed the rigor of the methodology.

A delegate suggested that not only the number of experts involved in a particular forecast potentially watered down the level of perception but that the selection of experts was itself problematic. Mr. Glushkov explained that experts consulted in the project are asked to submit a ranking of experts; the sum of these self-estimations is incorporated in the model. Furthermore, a strict, regular procedure in the project exists for extending the number of participant experts once the careful selection of initial experts for principal events is accomplished. Each initial expert designates relevant subgoals and the ten best people in the world for attempting subgoal problems.

Asked if advanced statistical methods fit in with the proposed substantiation technique or disrupted it, Mr. Glushkov replied that the system was a "self-learning" system. He explicated that many fine scientists at first make bad experts but participation in the process of making estimations and of determining subgoals improves their expertise as forecasters. Mr. Glushkov added candidly that The Institute of Cybernetics had not yet sufficient experience to evaluate the accuracy of predictions.

One participant asked what happened if experts drastically disagree, and asked if it is possible to identify critical nodes and to do a sensitivity analysis. Mr. Glushkov answered affirmatively. It was indeed possible to eliminate a particular opinion or set of opinions and observe the effect of this biasing on the final forecast.

Mr. Raiffa introduced Mr. R. Winkler, IIASA's staff expert on forecasting procedures. Mr. Winkler said that, to his knowledge, formal models did exist for combining expert opinions. However, when applied, these elegant models buckled under the weight of complexity, not only because of inter-related events but because of inter-relation of experts. The challenge was how to come close to a formal model for using expert opinion without rendering the model too complex to use. (The issue of optimal detail for a model was discussed in depth in the Automated Control of Industrial Systems conference.) Extant models and Delphi techniques amounted to little more than rugged "ad-hocism" in practice.

Mr. Raiffa explained that a considerable literature existed on the topic, including not only theoretical analyses but also descriptions of experimental work. In fact most of the questions surfacing during discussion were standard queries from the literature. (Indeed the existence of this body of information dispersed in publications of many various disciplines vividly illustrates a significant problem--subsequently brought to the attention of the conference -- the difficulty of information retrieval on a world wide basis at a time when information is growing exponentially.) Clearly, Mr. Raiffa stated, expert opinion and how to exploit it is a potential area for IIASA research; perhaps this might be tied to the matter of technological breakthroughs in computing?

Mr. Glushkov concluded this portion of the discussion by declaring his certainty that his institute would cooperate with IIASA as completely as possible if IIASA chose to pursue forecasting problems.

The discussion turned to a related topic: how to improve the interaction of experts. In the past it was impossible to store complete documents in a computer data bank. All extant information retrieval systems demonstrate the validity of that sad truth. Today, however, it is becoming increasingly possible to use computers to carry on scientific discussion, to update documents, and to index documents with comments. IIASA is ideally suited to "develop and maintain such a system relevant to IIASA's program interests."

A first step in such a direction has indeed been dared at Stanford, California. There, researchers with special interests in artificial intelligence have an entire booklet on line in the ARBA computer network. The text has been there for too short a period of time to examine accretions yet. Also defects exist in the on-line system (basically it is difficult to operate) which might impede widespread popularity of such a computer forum. Nonetheless, IIASA was urged to investigate the keeping of recent discussion documents on-line.

Discussion of IIASA Computer Facilities

Mr. Capriz believed no one would quarrel with his contention that IIASA must have computer services of the first order to support ongoing projects. It was his opinion that to secure top software personnel something of a bargain must be struck with the staff: in exchange for performing certain required services the staff would be free to avail themselves of computer facilities at other times to indulge their own research interests.

A contrary opinion maintained that essential programming work should be done by full time employees. The investigation of computer-related questions without explicit program solutions, the discovery of computer problems beneficial to the science should remain the prerogative of researchers not involved in supporting particular programs.

A delegate diverted discussion to hardware. His institution had purchased no major machinery of its own, but used a compact, economical display system, with a printing device connected with a number of computers. IIASA must not lose sight of the fact that the files which it will most likely wish to access are widely scattered.

Discussion of computer networking and the necessity for interfacing followed. There was general agreement that IIASA must look at itself in its present state as a systems problem. What role should computer support play? No single computer satisfies all needs. An in-house study with computer experts would be desirable. The basic stance of the participants was that any final decisions about computer acquisition should be taken professionally. IIASA's aspirations to deal with a broad range of problems requiring flexible computer services require that good communications with other hardware and adequate display be a primary concern. Computer support should be demand responsive.

Although in the course of the conference the question was reiterated what computer system seemed to delegates to be the most promising for IIASA's future, group opinion preferred to relegate the drawing up of any specific blueprint to a staff of experts--three or four who would investigate on a systems basis how to organize IIASA's computer support and how to plug into a variety of good machinery at minimal cost. Mr. Raiffa invited written suggestions about how to begin and what people IIASA should hire.

Attempts to Broaden Discussion

At the request of the participants, Mr. Raiffa described what sort of topics were discussed by other conferences. At the energy conference for example, delegates had discussed possible repercussions of the great discrepancy of energy use today between developed and developing lands. How to project the future of energy demand was debated--not only where it will come from but whether there is enough. Indeed, does man want to live in an efficient world? Thermal pollution stimulated speculation about consequences of possible climatic change. Or, more generally, delegates concerned themselves with the implications of what processes today are irreversible.

The computer systems conference might analogously wish to discuss various implications of the computer revolution for society. How for example, does computer density reverberate through urban and regional development activities?

A delegate expressed deep personal interest in the effects of communications media on previously isolated regions within developed countries. Current government research was hoping to ascertain through the use of models the social, economic, psychological consequences of mass communication media on "backward" areas of the world.

Other questions arose about labor and its interest and dignity in an automated society, about loss of privacy, and whether software should be taxed. Most participants, however, were disinclined to enter into such "imprecise" matters, feeling that discussion of such philosophical matters as how society has been or should be changed by computers was fine and good, but would not work as a subject of practical research.

One delegate favored studying computer impact and expressed his concern that necessary techniques are at present inadequate. He argued the indispensability of simulation to any study of impact and commented that existing packages of software for simulation projects did not admit sufficiently sophisticated artificial languages. He thought IIASA might profitably design a research project to construct a new simulation language incorporating features of languages used to attack special problems, queueing problems, and new languages. It was remarked that at present a rather appreciable gulf separates what we can already do with simulation and what we know of ourselves.

At this juncture, concern manifested itself over the real possibilities of the kind of networking cooperation in which IIASA expressed interest. A hard fact is that various member institutes have widely disparate computer capabilities. Can the terminals be arranged to connect them? Indeed, there is reason to fear that the present European telephone cable system is sadly inadequate to any nearly optimal networking. Hope was expressed that joint research into the prospect might soon begin and, wherever legally possible, an exchange of hard and software would ensue. Mr. Letov informed the conference that he would make available technical information about communication between terminals of member countries.

The information explosion was represented to the conference as a specter haunting society which IIASA might attempt to exorcise. How can computers play a role in containing the explosion? Indeed, if we regard information as all that which helps a man make a decision, IIASA cannot responsibly ignore the information explosion.

Applied systems analysis, it was suggested, might be brought to bear on the problem of how computers can assist WHO collate various medical information. A serious systems study of epidemiology as proof of what can be done was proposed.

Mr. Raiffa reported that just such an undertaking is now ongoing, and that IIASA could learn a valuable lesson from WHO's eagerness to cooperate. IIASA must not be too delicate about intruding into other people's fields. Personnel from different projects and groups in medical and biological fields had sought IIASA out to ask it to plunge into the picture, realizing that IIASA was uniquely qualified by lack of bureaucratic restraints to step back and look at their dilemmas with dispassionate, academic eyes. Furthermore, Mr. Raiffa explained that IIASA had earlier hesitated to raise politically sensitive issues for discussion. This had proved to be a self-inflicted over-sensitivity. Free discussion is essential to IIASA; there is no desire to embroil an embryonic institute in politically explosive projects--e.g. the short term control of energy--but at the exchange of ideas level the fewer inhibitions, the better.

Second Day

Software Policy for IIASA

Mr. Capriz recapitulated views expressed about IIASA software policy voiced tangentially during the previous day's discussion. The basic need appeared to be software to tie together non-standardized equipment. The pattern of scientists arriving to continue research at IIASA with momentum and with software packages of their own would apparently continue. Some software would require translation; IIASA can call upon programmers from member institutions to handle difficult transformations. Special attention must be given to the software of socialist countries to learn how to render it compatible with the IIASA computer system. IIASA's role as a clearinghouse for software packages already in existence was spelled out--a role requiring a small, permanent staff of experts.

Expressing approval of the suggestions for a software policy proposed in the paper, "Computers and Systems" (Document I), a participant reminded the conference, however, of essential questions IIASA should always pose before undertaking any specific project: Can the work be done elsewhere or is it solely appropriate for IIASA? Has the work in fact been begun elsewhere or perhaps shabbily handled? If IIASA fails to attempt the work is it likely anybody else will?

Others offered further support for the submitted proposal on the grounds of its feasibility. IIASA most probably could link up with computers designed to be operated from the outside. To do so a terminal is needed that works over telephone lines. IIASA's hardware must be capable of "pretending" to be a terminal capable 1) of emitting a file so that distant machines believe it is typing the file out, and 2) of taking information back in, editing it, and storing it in files. IIASA's hardware must be able to "pretend" to be terminals at different speeds and to make transitions between character sets. A small computer with disk file might suffice. This would be a reasonable project with modest results but one which requires patience.

The conference participants entered an animated discussion of alternate methods to speed transmission and transfer. After citing various ways to accelerate transfer including dedicated lines and closed circuit TV cables, it was pointed out that for IIASA's purposes the transfer of complete files would be a rare and improbable enough phenomenon not to cause anxiety--when complete files were needed the situation would be apparent long enough in advance to relay requisite material gradually during "off" hours.

Consideration of speed promulgated estimates of cost for various means of transmission. Opposition solidified against any attempt to do a cost estimate without reference to specific equipment, times, and locations. Costs are in any event usually negotiable. The entertaining information was presented to the conference that to lay a line from point A to B in Europe may cost as much as 25% more than to lay a line from point B to A.

Discussion was resumed upon "Computers and Systems," but delegates were reluctant to engage in conversation about software for systems analysis without details or reference to particular projects. One participant recounted the following story:

> "Once, long before computers, Mr. X stood talking with Mr. Y. Mr. Y inquired how long it would take him to reach the river. In reply Mr. X said merely, "Go." Mr. Y repeated his question but the only response he extracted was again monosyllabic: "Go." Disgruntled, Mr. Y set off in the direction of the river. He had only taken several strides, however, when Mr. X called out, "It will take you two hours." Whirling about, Mr. Y said with annoyance, "Why didn't you kindly tell me that when I asked?" "Because, my friend Y, although I knew how far away the river was I had no idea how fast you walked."

The participants all agreed that when concrete software problems arose during IIASA projects these should be tackled and solved. Whatever is learned from the experience should be applied to understanding of software necessary for systems analysis in general.

Mr. Raiffa affirmed the fact that IIASA was already involved in projects which have produced concrete software problems. When those at work in the energy project on thermal pollution and climatic change did a survey of existing software in USSR, UK, and USA, they found that existing models could not cope with the possibly different consequences of point sources versus diffuse sources of waste injection into the atmosphere. Their discovery and discussion about possible approaches to constructing meaningful models referred back to manpower nuclei now hard at work communicating with each other on the subject.

One foreseeable IIASA project involves global modelling. How the global modelling project appears to be gathering momentum fits with the terms of "Computer and Systems" proposal. A number of prominent centers of current research have expressed willingness to send software packages to IIASA for others to scrutinize and comment upon (The World Dynamics Project, Global Dynamics in Holland, Mishibuti in Japan, Leontief's UN group). Mesarovic and Pestel, at work on hierarchical decentralized programs--the world divided into ten regions--anticipate holding a week long symposium in February 1974 at IIASA. They have volunteered to send programmers to Laxenburg months in advance of the meeting to work out implementations of their programs. All major groups mentioned above have different packets. In the interests of making cross-cultural comparisons, IIASA wishes to convene the groups for profitable exchange.

A delegate voiced his doubt that such a project or projects were practical. Compiling packages addressed to the same problem was "like building the tower of Babel in reverse." Is IIASA's idea merely to become a mailing address making various programs available to correspondents? Is rating them a goal? The delegate cited personal experience with time-consuming attempts to differentiate among only five or six software packets simulating a university; the world is somewhat more complex than a university!

Mr. Raiffa now attempted to imbue the adjective sophisticated in the phrase "sophisticated clearinghouse" with its full force. IIASA aspires to analyze and to disseminate reactions to software. Actual rewrites and improvements--as in thermal pollution models--remain an activity for member institutions better equipped for manpower-intensive projects. Laxenburg is not destined to be a pigeonhole.

When asked what a flourishing global model group might have to gain from IIASA, Mr. Raiffa enumerated three services the Institute could perform: 1) provide resident experts to assist in the solution of particular, especially methodological problems; 2) open communication channels between research in socialist and non-socialist lands; and 3) offer disinterested criticism.

It was announced that a clearinghouse for software in operation within the USSR has proven practical and helpful.

The suggestion that conferences might be an expedient form for rendering the clearinghouse function met with a general response that such conferences, while necessary, were not in themselves sufficient.

Acknowledging the "Tower of Babel situation" in contemporary software, a delegate proposed formally that IIASA commit itself to research into problem-oriented languages (Document N).

As an integral part of IIASA's approach to providing adequate computer support to ongoing projects, a delegate thought specialists in formal languages would be a valuable addition to IIASA's staff. These few specialists might provide consultant services for member institutes, advising both how to formulate and how to solve problems--two distinct operations, the delegate insisted.

IIASA's peculiar strength, a delegate told the conference, is certainly its ability to make results elsewhere better known and more useful to many others. He acclaimed the multiplicative effect IIASA can have on research and exhorted IIASA not to embark on its own language development program which would bog down the Institute, diminishing its potential for practical achievement.

Perhaps, a delegate thought, it would be best to study the development of language only as the need arose from a real problem, not in general. Experience has taught the advisability of proceeding to the general through engagement with specific problems. In IIASA software specialists should work side by side with the staff of various projects.

In agreement a delegate recounted how attempts to implement a general hospital information system throughout Canada met with a succession of dismal failures. Early confidence was overwhelmed by the suffocating generality of the adventure. In contrast a research project in Vancouver has recently concerned itself with arterial by-pass surgery; working hard--though encountering resistance from some medical people--a team managed to analyze in a year six hundred individual cases, but no more. They have a feeling, however, of accomplishment. IIASA might be well-advised to keep track of such specific projects in the medical process field and to correlate achievements.

After mentioning that Harvard Medical School had recently asked IIASA where to obtain an analyzed set of by-pass surgery records, Mr. Raiffa in effect seconded the remarks of the previous speaker. The minutes of IIASA's Medical Conference reflect an entrenched pessimism in the United States about the likelihood of achieving any helpful vast information system. Indeed, this is a universal problem. IIASA might review successful, operative systems to see what lessons they have to teach.

More generally speaking, one delegate felt IIASA is in a singularly good position to engage in pure research into validation and devalidation procedures for operational systems and models.

At least, another opinion was ventured, if IIASA did in the end orient its own computer system to many computers in many countries, it had a sound opportunity to serve as a trial ground for different programs in systems analysis before converting software at program level to other machines.

If a conference in global modelling might not permit participants to delve deeply enough into central issues, Mr. Raiffa stated, nonetheless, perhaps there were other subjects related to computer systems on which scientists would welcome the prospect of conferences. These would be subject areas with an overlap between the international implications of computers and non-computer activities. A delegate endorsed the idea of working conferences among participants actively engaged in a particular project; this would promote comparison of notes in progress. Mr. Raiffa assured the conference that such sessions would be standard procedure linking in-house researchers and member institute staffs.

Various delegates felt IIASA could sponsor useful conferences on numerous computer-related problems and proposed:

- a conference with a high information content level on work transpiring in the data community
- a conference on control and application of computer networks
- a conference to discuss varieties of software currently in use, and their merits and limitations.

Review of Ongoing IIASA Projects

To assist delegates envisioning the nature and extent of IIASA's computer needs, Mr. Raiffa and various project directors summarized the research strategies of the Water Resource Project, Energy Project, Ecology Project, and Urban and Regional Systems Project.

Water Resources Project

Mr. Letov, Director of the Water Resources Project, described intentions to design a complex mathematical model of water resources distribution, including economic aspects of global interest: how water as source of energy should come to industry and agriculture; how water should provide transportation; how ecological equilibrium in some regions might be safeguarded. The projected model will contain not only the usual constraints on a linear and non-linear program, but also continuous types of restraints involving differential and integral equations. A special feature of the model is that it attempts to include admissible alternative ways of supremal goal achievement. Because the supremal goal shall include contradictory interests not only scalar-valued optimization is relevant but also vector-valued optimization. The dimensionality of the model will be high which makes collaboration with the project on optimization of Large Scale Systems inevitable. An essential part of the project is to investigate the sensitivity of the model to external disturbances. Not all elements of the model can have adequate information; therefore fuzzy sets will be invoked to deal with floods, droughts, and other such cataclysms to which it is impossible to assign any standard probability.

In response to a request Mr. Letov diagrammed a subgoal of the disaggregated model on the blackboard. Skepticism was expressed about the possibility of making such an ambitious model actually fit local conditions. How to evaluate particular parameters was a thorny problem. Mr. Letov explained that he will shortly issue a strategy paper for his proposed research and that the project was not yet committed irretrievably in any direction.

Mr. Raiffa supplemented Mr. Letov's presentation placing emphasis on applied systems analysis aspects of the project. He explained that the goal of the Water Resources Project was to find a way of meaningfully influencing day to day policy within four or five years. Models and research are essentially a background for decision making. The purpose of iterative bringing in of data and of breaking down a large model was to isolate decision problems. Detailed modelling of a large river project is not a task of the immediate present. It was considered desirable to probe into recent large studies of rivers (the Vistula, Trent, or Delaware-Potomac) with the cooperation of teams engaged in the work, to discuss their experiences and to learn how these can help in planning future studies. The Water Resources Project aspires to bring together formal and analytical past attempts--including existing software--and to improve the methodology. Past projects have legal and political lessons to teach as well. Hopefully it will be possible to establish a network of experts on particular local problems and to invite groups involved in water resources studies to attend forums on strategy problems.

It was also felt important to take a concrete problem of limited scope and to work it through from beginning to end to verify the value of a rigorous systems analysis approach. IIASA is now committed preliminarily in such a project in the alpine lake area which will involve cooperation with groups (including legal experts) in Vienna and Innsbruck who already have experience with studies of enclosed small lakes. The agreement of the United States and the USSR to study Lake Tahoe and Lake Baikal adds a dimension of urgency to the undertaking as a sort of pilot project.

Repeating IIASA's goal of achieving diffuse interfacing among projects, Mr. Raiffa explained that the staff is now considering various overlaps of the Water Resources Project with other areas. The Design and Management of Organizations Project might, for example, choose to study the Danube from the point of view of what commissions regulate river activity as its blue water flows from nation to nation. IIASA's Medical area is clearly concerned about the provision of potable water in developing countries. Thermal pollution naturally links the Water Resources project to the Energy Project.

Energy Systems Project

Mr. W. Haefele, director of the project, explained that IIASA is particularly interested in systems aspects of energy. He identified a dozen principal areas of concern (the asterisk* indicates "computer intensive" areas).

1. Screening of data concerning availability of natural resources--including renewable energy sources (solar, tidal, wind). Sifting data is necessary because of glaring inconsistencies in data commonly cited. An activity best performed by member institutes, not IIASA itself.

*2. Energy modelling to ascertain priorities for research and development; models simulating demand and supply; comparison of energy sector models, environmental standards.

*3. Information retrieval from energy sector models.

4. International market study (with IAEA).

*5. Climate and water--the effects of energy. Mankind's problem in the long run is probably not fuel supply but disposal of wastage. Large climatological models are needed which will tax present computer technology to its limits. Programming is not envisioned at IIASA but results will be factored into the study.

6. Synthetic hydro-carbon fuel study. Part of an investigation of new intelligent uses of coal which will involve strategic evaluation of best uses of energy sources over time.

7. Nuclear economy. Attempts to identify nuclear economy as a system with systems problems.

8. Scenario writing for a world with practically unlimited resources (nuclear fission, fusion, solar and geothermal power).

*9. Risk evaluation.

10. Accountability. IIASA hopes to benefit from IAEA's experiences of large scale defense build-ups.

11. Global monitoring, probably with geostationary satellites (a data intensive activity).

12. Standards and Public Acceptance. A methodological study.

Mr. Haefele then said that since the majority of increasing energy demands in the future shall come from developing lands there is little cause for relief that developed countries appear to have reached a saturation point in the use of energy and may in fact be tapering off. Conservation shall become necessary.

Answering the question about what software he anticipated needing for modelling activities, Mr. Haefele explained that after considerable preliminary screening in the USA, IIASA had identified ninety existing models to compare analytically. In addition, a recent conference at Alma Ata with representatives from France, UK, and USSR featured numerous other models of importance. Evaluation of present models and construction of a new model is a goal.

A delegate wished to emphasize the value of having eventual programs--no matter how intrinsically complex--easy for the user. The degree of aggregation in energy models at present differs widely. A range of dissimilar models has produced general dissatisfaction. IIASA can perform a service by streamlining the models.

Mr. Raiffa commented that one reason IIASA had chosen to deal with Energy is the assured cooperation of IAEA in Vienna with large computer facilities and many valuable contacts. Oakridge Laboratory has also demonstrated an eagerness to participate in the project. Data compilation will in every instance be a joint venture.

"What is IIASA's approach to data analysis?" a participant asked at this point. "Have you opted for standard procedures, batch mode or heuristic techniques?" Mr. Raiffa replied that IIASA had not yet decided what the best approach would be. An expert committee to give advice on statistical matters is now preparing a report.

A discussion followed about the advisability of sending IIASA staff to work at any of the computer installations equipped to handle the computational needs of climate investigation on a systems basis. Some definitely favored retaining all working personnel in Laxenburg.

Mr. Capriz confessed to "going up and down" trying to assess IIASA's computer needs. He invited delegates to say when concrete project reports triggered new sentiments about computer facilities. Mr. Raiffa expressed sympathy with the co-chairman's puzzlement. Dramatic variance in computer needs varied not only from project to project but also within projects over time. In attempting to answer the question, "Can IIASA continue to function with its present hardware?" one might ask if perhaps the value of superb equipment as a lure to attract superior leadership should weigh heavily in favor of expansion.

Ecology Project

1. Mr. Holling, director of the project, brought with him to IIASA people experienced in regional models and relevant software. The project is designed to involve management. Graphic displays in a decentralized way are desirable for this end. The sensitizing of implementers is an integral part of ecological problems; interaction also important for modellers. The goal of interaction puts a requirement on kinds of computer facilities needed.

2. Theoretical research on "resilience" and "equilibrium." This aspect of the project will draw upon simulation and analytical work involving stochastic probability which is going on in a magnificent manner in USSR.

3. Defining environmental standards and monitoring procedures. Work in this connection is vital to various UN agencies. People currently involved in modelling often want basically different data from what has been collected. IIASA will endeavor to link model makers and data collectors, monitor the monitoring, make sure "correct," pertinent data collection is carried out. IIASA's role is not to gather facts but to complete feasibility studies.

4. A small scale, concrete manageable problem seen through from beginning to end with an applied systems analysis orientation--i.e. the alpine lakes project.

Urban and Regional Development Project

This project is new; IIASA is awaiting news that the chosen project director can accept the position. The tentative program will include a study of different national settlement policies and of the founding of new cities. The project will also deal with demographic forecasting and the effects of growth on cities and conurbations. Modelling activities will simulate present urban systems with emphasis on management of municipal systems (fire control, solid waste disposal and sewage, hospitalization). Kinds of information systems within management areas are of particular interest--do they work? are they transferable?

Mr. Raiffa expressed his hopes that the previous rapid summaries of IIASA projects might suggest to the conference the immediacy of the need for computer support. Mr. Capriz referred to a letter sent by IIASA to project leaders in May 1973, requesting them to specify their computer requirements in the short run, and asked if there were useful answers.

Mr. Raiffa replied that difficulties in finalizing personnel has rendered such specifications either impossible to acquire or of uncertain accuracy. Leadership in an international institute is especially tricky. A number of projects (Bio-medical, Urban and Regional Systems, Optimization of Large Scale Systems, Automated Control of Industrial Systems) had not yet identified needs in detail. Furthermore, the present conference would hopefully anticipate what needs might be generated internally by an adequate computer section and what a commitment to artificial intelligence research might entail in terms of necessary hardware investment. Two projects in the formative stages--if IIASA chose to enter into the fields--would certainly require intensive use of major computer equipment: investigation of the role of artificial intelligence in medical diagnosis (Minsky and Schwartz), and optimization of large scale systems (Dantzig, cf. IIASA Brochure 7.5).

A delegate commented that any and all IIASA projects would most probably incorporate elements of optimization work which requires intensive computer support. IIASA researchers may need more than a front end small computer hooked up to large ones elsewhere.

IIASA's Computer Division: Present State and Plans

Mr. S. Neuschl, Head of IIASA's Computer Section, described the raison d'être of the computer section as support. At present scarcely any research into computer sciences is planned. IIASA's computer section should be user oriented: those with demands should be able to state in a simple form what they want and to receive comprehensible answers within a reasonable time. Mr. Neuschl cautioned the conference that a high standard of service required careful maintenance. Qualified personnel is a fundamental necessity. Hopes are to achieve an interactive on-line computing service adaptable to new demands.

In general IIASA's long term aim is to avoid an <u>ad hoc</u> approach but to tailor an expandable yet elementary interactive system--no easy task as such a system will require extensive research. Mr. Neuschl outlined a possible research project concerning computer systems which included among other objectives a foray into non-numerical programming methods.

A chorus of delegates warned IIASA against being too overambitious at present. It was suggested that computer section people should play no role in computer research. This subject arose several times during the conference. Delegates evinced two minds about the desirability of computer staff wearing "two hats," i.e. working in support services and pursuing scientific projects simultaneously. A compromiser advocated "two hats," but only if they were of quite different sizes! The conference was reminded of the difficulty of attracting first rate computer scientists to IIASA if they must solely perform service functions and never enjoy liberty to indulge their own interests. There seemed finally to be general agreement that whereas in a small scale operation scientific capacity was not necessarily a disqualification from leadership, having a manager, not a scientist, to supervise a computer support division has distinct advantages.

Mr. M. Thompson informed the conference in more detail about the present state of IIASA's computer section. He catalogued hardware in use: four interactive terminals (two Honeywell Bull, two Hazeltine) joined by cable to Frankfurt and via satellite to Cleveland; a Control Data remote batch station. Plans have been formulated to increase the capacity of the remote job entry station through "System A" (including graphic display, plotter and tape unit). Current demands and desire for maximum flexibility have led to consideration of purchasing a mini-computer. The purchase would allow IIASA to have an independent modular system that would "stay up" despite compound catastrophes. The mini-computer would satisfy stop-gap program necessities, relieve IIASA from ulcerous worry over all too fallible phone line connections between Laxenburg and Vienna, lower the absolute cost for interaction applications, and provide rapid graphic display capability. In conformity with the advice of a committee meeting last May, requests for proposals were sent out to mini-computer manufacturers, and the slate of eligible machines reduced to Data General Nova 840 ($184,000) and Hewlett Packard 3000 ($311,000).

In response to this report a delegate said that he felt detailed engineering study should precede even the purchase of a mini-computer. Mr. Raiffa concurred in the value of such a study which would indeed be automatic in any established, ongoing institute. IIASA was in something of a "chicken or egg" situation, however. The actual decision to purchase equipment had been postponed until consulting the conference, but IIASA was continuing day-to-day to pay penalties: the staff is burgeoning; the current arrangement is expensive to use; telephone wires are creating periodic havoc. With a minimum of six or seven months lead time for ordering a computer, delay might gravely retard actual operations. Investigations into computer rental had disclosed that rental was cost prohibitive. Awaiting the detailed specification of all project directors--assuming accurate specification in advance was possible--might risk disquieting frustration of IIASA scientists. Mr. Raiffa pointed out that to date IIASA has had CDC remote batch equipment at its disposal without payment. A choice to purchase a mini-computer now did not, considering the level of expenditure and continuing usefulness of such a machine, inhibit the purchase of major machinery later. Although IIASA is certainly not today in a desperate state, some projects are already aware of needs which exceed in-house capacities. A decision must shortly be taken.

Report on Cyber 73-74 in Vienna

Two heads of the computer section of the Technical University of Vienna addressed the conference on behalf of the Cyber 73-74, the computer with which Mr. Raiffa had earlier mentioned the possibility of hook-up. They reported that the Cyber could serve IIASA with batch and real time compatible compilers on large scale machines. It was asserted that the machine would be installed by the end of the year, with test runs conducted in January, and by the end of February would be ready for professional use with all batch and interactive computer facilities existing.

The Cyber advocate expressed his opinion against the value of a mini-computer for IIASA; such equipment was, he felt, too time-comsuming and soon exhausted its core when application programs for scientific work were run. In response to a question it was revealed that the Cyber would have an initial core of 92,000 TCS words which would expand in 1974 to 250,000. Costs were characterized as "positive for IIASA."

Various delegates expressed the opinion that the Cyber hook-up would be attractive for IIASA; scientists with such a time-sharing service would not suffer from deprivation. Also on grounds of initial facility management, it was perhaps advisable for IIASA to join Vienna, postponing the acquisition of a mini-computer and chanelling full energies to application tasks. Meanwhile time would be available to study on a systems basis the IIASA computer section, not only optimal machinery but also organization of staff. A consensus emerged that prior to making a permanent commitment to any major hardware, better determination of short, middle, and long term needs was essential.

A brief history of the decision making process which preceded Austria's purchase of the Cyber 73-74 revealed that computer science value of the equipment had not been a consideration. The Technical University of Vienna chose the Cyber because their benchmark survey had advised a "number-cruncher" and not a machine capable of editing.

Mr. Capriz asked the Austrian delegation if it was their opinion that a machine at IIASA capable of doing what the Cyber could not do would help the community. The answer was affirmative. Computer science work was now nascent in Vienna and Linz, both conveniently close to Laxenburg.

A delegate commented that although the pending possibility of a January hook-up with the Cyber in Vienna might reduce the value of a mini-computer for IIASA time-sharing, as a concentrator and for graphics display such a machine was still desirable. Mr. Capriz reminded delegates that even with the Cyber, interfacing problems previously discussed remained. In this vein Mr. Raiffa again expressed concern for socialist scientists arriving with software. Mr. Glushkov proposed including a socialist expert from this institute in IIASA's computer section to investigate compatability procedures. Mr. Thompson added that IIASA has already investigated lining up machinery for scientists arriving with assorted software and for scientists wishing to take packages home: an IBM 370-145, a 370-155, a Univac 1106, as well as the Cyber will be available to visiting IIASA scientists.

The matter of computational methods arose. Was there expectation of collaboration with numerical experts outside of IIASA? The rising dimensionality of problems was particularly daunting. Mr. Raiffa responded by stating that IIASA's optimization project would have a heavy mathematical orientation. Special appointments were always a possible solution to scientific deficiencies but IIASA at present appears well-placed; indeed, Vienna is a center of numerical research. Prague and Munich also offer excellent resources. The walls of Schloss Laxenburg should not be conceptualized as a circumference in any sense but rather a point at the center of a human, mechanical, and financial network of practically limitless potential.

Third Day

Artificial Intelligence (AI)

Mr. Glushkov cursorily classified what he considered principal areas of research within the field of artificial intelligence: theoretical problems, the design of technical devices to substitute in whole or part for human beings, the creation of special software, and robotry. Within his own Institute of Cybernetics Mr. Glushkov regretted limitations of experience and acknowledged that no perfected and strictly quantitative methods were yet in use. He told the conference that because artificial intelligence research was extraordinarily expensive, he doubted that it was an appropriate field of inquiry for IIASA during early phases of the Institute's operations.

Research Developments in National Member Countries

Once again delegates insisted that their reports were in no way all-inclusive or infallibly accurate. A spectrum of various interests and activities was brought to the attention of the conference. Total investment in artificial intelligence research differed dramatically in different countries, but certain preoccupations, attitudes, and ideas recurred. Strong feeling was expressed that progress in language development was prerequisite to significant artificial intelligence advances. There was disagreement about the value of predicate calculus and heuristic search. Rather than claim what can be accomplished with these tools, proponents attributed pessimism and failures to impatience. Sentiment crystallized that particular techniques being refined in AI were applicable to many IIASA enterprises but general AI research was forbidding. Dangers of over-inflated expectation were cited. Despite different points of departure it proved possible by the end of the conference for delegates to collaborate and produce suggestions for an AI research strategy that evoked general approval (Document C).

United Kingdom (Mr. Longuet-Higgins). There is broad interest in using perceptual information for motor purposes, a field with interesting implications for discovering the physiological bases of psychology. A special case involves effort to relate visual input and manipulation. A machine has been developed capable of assembling small objects, fitting together a motorcar composed of four wheels, two axles, and a chassis. Of course, as in all such current projects, the operation is possible only within a rigidly standardized environment: a "glimpse of a white piece of paper" incapacitates the assembling machine.

Another project to use perception to guide action concerns formal description of vision directed towards fulfilling a need for a structural theory of recognition of objects in a two dimensional visual field. Researchers are developing a program form with which to capture the heter-archical nature of cognitive processes. This work has practical applications for engineering projects attempting to utilize visual information whether on the surface of the moon or on the ocean floor. Work is also going on to construct a tactile robot, for the feeling exists that other sense modalities should be considered for input.

In the area of computational logic there is a major project concerned essentially with how an information processing system should take in information and determine if it is consistent with the existing data base. This enterprise is fundamentally a matter of automatic theorem and problem proving--proving a program will implement a particular algorithm--and is relevant to establishing the certainty that a plan will achieve specified goals.

In computer-aided construction, computers are presently pressed into service to model the process of learning in human beings, an excursion into educational psychology which may be of particular interest to IIASA. Those at work with natural languages are attempting to make a formally precise model of human cognitive processes, an endeavor to exploit fully linguistic insights into language. Work is continuing with LISP and micro-planner languages. A program now exists which makes correct use of modal verbs in English. Researchers are also developing a high level programming language which aims to formalize problems of making and implementing plans in the real world.

Research in automation of game playing perseveres.

German Democratic Republic (Mr. Klix). The overall state of AI research in GDR is vast, involving a research program in cybernetics which includes:

- hardware developments for pattern recognition

- optimization of man-machine communications

- the analysis of organismic and congnitive information processing.

Previous discussion suggests that one particular area--problem solving--has particular relevance for IIASA. Indeed, in discussing problem solving technique and its optimization as a task in AI, and in drawing suggestive links with applications in industry, the economy, and management, the potential value to IIASA of pursuing the topic will hopefully become clear. Mr. Klix chose first to survey developments in problem solving research, to report on work in progress, and then to suggest areas of application.

What is a problem and what are the essentials of problem solving techniques? To define the problem we distinguish three components:

1. The initial state z_o
2. The end state z_e (often the goal itself but alternatively an optimal algorithm)
3. Rules, i.e. a set of operations together with conditions under which they may be applied. (Operations transform a given state into another, if applicable. A sequence of operations may be described as a path in a graph.)

A problem in its broadest sense arises if one of three components, or at most two, are not defined or given explicitly and must be sought. This method of classification permits the ordering and handling of real life problems. Synthesis problems in chemistry, in mathematics, in planning as well as in model building itself, involve the type of problem where Point 3 is unknown. Analytical problems in chemistry--determining the structure and the age of minerals--are problems where Point 1 fails. Finding a possible set of solutions for special types of differential equations in mathematics, for fitting model conditions, or for arriving at appropriate decisions are a third set of problems where Point 2 is unknown.

What is problem solving research within artificial intelligence? The study began originally with GPS developed by Newell, Shaw, and Simon: an instrument capable of identifying different logical terms as equivalent or not. Today the applicability of limited GPS procedures to various problem types is not quite clear. Computer linguistics superceded GPS. Thue and especially Semi-Thue systems contain basic principles of foremost significance here. Algebraic and logical calculi-like graphs or the concept of an abstract automation or that of a generative or transformative grammar are at the foundation of the rising theoretical framework. The idea arose of using formal languages to map problem solving procedures as a special type of information gaining, using, and processing technique, a so-called "first order approach." The search space becomes, at least in its path properties, differentiated by the linkage of operations, by the proof of its applicability, or by the rewriting of the states within the space.

Clear cut areas of contemporary problem solving research are 1) the development of question-answering systems with deductive abilities, 2) the handling of classification tasks, and 3) the design of problem or system-oriented languages. Indeed, the role of question-answering systems arises in the implementation of natural language statements which demands the construction of self-organizing semantic nets, a task with many applications in automated data processing and retrieval processes. A crucial point for the derivation of theory is that there has been until now no information measure for handling semantic problems. There have been proposals for measuring the structural information content (e.g. the complexity of algorithms) but no successful effort for measuring the semantic information content. Such measurement is nevertheless essential for addressing language problems in a sophisticated way, especially problems related to conditions and properties of comprehension and to use of natural language.

Applying problem solving research to classification tasks entails the construction of a graph, especially a decision tree over the properties of the object set to be classified. After constructing a minimal tree (an algorithm exists which minimizes the decision expenditure), it is possible to apply the schedule to numerous different tasks. In medical diagnoses with given properties, effective classification has been accomplished of heart illnesses and neurological syndromes. The high economical efficiency of such research is a function of the fact that the same logical and mathematical construct is adaptable for many different practical classifying techniques.

Here is a point of special interest: it is possible to analyze the classification procedures of intelligent subjects, e.g. trained medical men, studying their cognitive risk-taking in decision making until achieving a program which describes their classificatory behavior, behavior using fewer decision points than formal solving because of assumed special strategies. There was a signficant difference between the efficiency of the program established solely with the means of artificial intelligence research and that derived from analyzing the efficiency of gifted persons, i.e. the efficiency of natural intelligence. Decision procedures of gifted subjects are more efficient. Why?

Natural intelligence indeed reveals its most characteristic properties in human problem solving behavior. Computer languages like LISP or REFAL are only appropriate for mapping the most efficient, i.e. heuristic, strategies where the information content of a whole problem space is used in making local decisions. That means too that simulation programs of human problem-solving are appropriate for the development of efficient algorithms. And there are strong relationships between algorithms and the software type. Simulation programs involve contributions for the development of program-adapted formal languages. They are one potential source of discovery leading to the attainment of a scientific foundation of programming languages *per se*.

The continuation of classification research is leading to ever more sophisticated algorithms, as well as to entirely new principles. Obviously, mathematical investigations on fuzzy logic and fuzzy sets allow more complicated tasks to be performed more simply. It thus becomes possible to realize minimal costs for class procedures within overlapping sets, and without seeking a clear-cut limit as in classic pattern recognition tasks.

Other new directions of research have sought to find substitutes for predicate calculus which is not flexible enough, i.e. sensible enough for reflecting essential properties of natural language now in use. Special types of so-called Case Grammar lead to special kinds of operations which are suitable for mapping (e.g. which link and decompose the natural units of semantic memory). Three "levels" of language and communication are involved: 1) the level of concepts which may be handled by Boolean functions, 2) the level of events for which new operations are appropriate (e.g. actor, instrument, location, duration, and their inverse), and 3) the complex level where so-called scenes--aggregations of natural memory units--come into being. Within such clusters it is possible to derive new statements from the given network.

A further application area of classification research concerns the optimization of man-machine systems as a special case of large scale systems. Optimization means to make well calculated compromises. The techniques of polyoptimization, strategies of decision making at different levels of the hierarchy, the decision order classification of states, and the appropriate use of feedback of information are pertinent subtasks of artificial intelligence with considerable mathematical background in common. Again, the treatment of semantic aspects in the coded information offer is a crucial problem for achieving an optimal training algorithm to reduce the failure rate in decision behavior. Signal detection theory is only the first order approach for handling this topic appropriately.

Two examples of practical applications of programmed problem solving procedures involving the decomposition of sets are the automated design of pressed conductor plates and the automating of electrical equipment in a heat power plant.

In his summary Mr. Klix asserted that certain key problems in problem-solving are in fact interdisciplinary and highly relevant to IIASA:

1) Automated classification of space,

2) Development of efficient algorithms for heuristic strategies, and

3) Programs for storage and self-correction of information.

Most pressing of all, however, was research into semantic nets.

USA (Mr. McCarthy). Mr. McCarthy portrayed Artificial Intelligence as a way to describe the interests of men who have spent the past twenty-five years trying to make computers do things which seemed intelligent when human beings did them. The great practical value of AI research has been delineating the boundaries of straightforward programming. At present among the ranks of those involved in AI dissatisfaction rages. Scientists simply do not yet possess the battery of ideas which must precede the construction of a machine intelligent on the human level. There are a number of ambitious projects in operation, but those involved are helpless to forecast whether the necessary ideas shall occur in five or in one hundred years.

Mr. McCarthy thought it perhaps useful to classify Artificial Intelligence in terms of sub-problems:

1) Heuristics: exploration of spaces of alternatives--game playing, theorem proving;

2) Methods of determining what information is available and how it should be represented in the computer--basically a matter of achieving proper division of information into procedures and declarations;

3) Automatic programming: compiler writing, but intensive, capable of going from collections of information sufficient to determine how a problem should be solved to solving the problem;

4) Models: how to take a problem stated in ordinary talk and put it into a model;

5) Learning and Automatic Generalization--considerable progress is first necessary in representation area;

6) Communication: separation of pieces of information to be delivered to discrete destinations; and

7) Perception.

In describing ongoing research in the USA, Mr. McCarthy emphasized work in perception and in procedural representation of information, i.e. new languages. Considerable efforts are being made in low level vision (distinguishing shapes of three dimensional objects, edge finding, color identification) and in high level vision (making models of what has been seen with manipulation as an application). He mentioned projects in natural languages, automatic programming, speech recognition, theory of computation (proving that algorithms have desired properties), and spectographic analysis.

Discussing the possible relevance of AI to applied systems analysis, Mr. McCarthy ventured his opinion that IIASA would provoke no criticism if it opted to by-pass AI despite the fact that certain potential applications would be valuable--e.g. question answering systems, matters of heuristic search. He described a project which interested him personally: an attempt to formalize facts and to formalize policies based on facts--springing from the conviction that a proposed policy should be proven to be best. It will then be possible for anyone beyond the power structure to propose improvements in management, and in government. Policy will thus become independent of persons and impose a self-checking process on decision making with profound political implications. This project is still very much in early conceptual stages.

"How do you envisage question and answer systems as relevant to IIASA interests?" Mr. McCarthy replied that he felt two issues were involved: 1) analyzing sentences in natural language, and 2) deducing answers to questions from facts, i.e. information retrieval. A possible project now being explored in Stanford is taking the past year's news as reported by AP and reading it into a computer which classifies stories and stores news on disk files. People are now considering writing a Q-A program based on this data base. IIASA would certainly be interested in developments in improved information retrieval systems.

Austria (Mr. Gordesch and Mr. Firneis). The Austrian Academy of Sciences has committed itself to only limited work in AI because experts forecasting the future gave depressing advice. Not much funding is available and present hardware is inadequate.

Czechoslovakia (Mr. Ulcek). The present state of the art of AI in CSSR is characterized by extensive basic research. A recent conference in Prague discussed ramifications of information theory and decision theory. A number of machines exist that can perform translation tasks and speak on an elementary level.

Italy (Mr. Mantanari). AI work is a matter of generally small scale operations; few scientists are fully engaged. Earliest work done was in picture analysis and description.

Today, the trend is towards applying heuristic search procedures to optimization problems and to the programming of semantic memories with the goal of learning. The phrase, "a tentative applied approach," may do the situation justice. Work in speech recognition and formalization of search will ultimately culminate in the development of a language of QA 4 type which might eventually facilitate the testing and correction of software.

Poland (Mr. J. Kulikowski and Mr. R. Kulikowski). AI research is oriented towards practical results. Reiterating a theme growing familiar, Mr. Kulikowski stressed the importance of IIASA's sharing a belief in the importance of the pragmatic approach.

Present work is in experimental data processing (e.g. attempting direct input of medical radiograms with considerable interpretation of the received image) connected with medical and biological goals. Automization of experiments is a distant future aim: possibilities of detecting cancer at an early stage, identifying parasites in pork, performing micro-minerology analyses.

A longstanding aspiration is to solve problems of pattern recognition at three levels:

1) preliminary identification of visual information,

2) recognition of local features--linear description of the contents of an image, and

3) semantical interpretation of an image--a formal language for picture data such as Picture Argo 1,2,3.

Researchers are demonstrating a preference for non-classical logic tools, e.g. tense logic, in their attempts to establish the consistency of constraints over large scale systems. Operational control within systems is receiving attention. Topological logics are preferred to fuzzy set theory in describing disruption of large scale systems caused by external events or in describing anomalies in pattern recognition to which it is impossible to assign a probability measurement.

The advice was offered that AI experts should function within IIASA only in intimate relation to particular program problems. A small group of semantic experts, for instance, might help with interpretation and translation of data within the Medical Systems Project.

France (Mr. Cadiou). No large research group is active in AI. Scientists pursuing the subject are loathe to admit it publicly because those allocating funds are not overly enthusiastic. A program has been produced which is now employed in industry for automatic classification. Current interesting work is related to understanding natural languages, the elimination of ambiguity from statements by semantic analysis backed by a theorem-proving apparatus written in predicate calculus. A project is underway to try automatic theorem proving in higher order logics. Elsewhere researchers are attempting to achieve a theory level understanding of the semantics of programs. What is restrictive about most programming today is how specific it needs to be, whereas in real life one can afford to be a bit vague in approaching problems. One would like an amiable computer capable of asking the programmer, "What do you really mean?" Such work is related to a project to implement an interactive system for helping to build programs that involve checking for consistency at each stage, a program employing predicate calculus which reminds the programmer of what he might have forgotten.

The French post office and telecommunications center are engaged in pattern recognition research.

Bulgaria (Mr. Dobrev). AI has only limited facilities; much ongoing research is done in collaboration with experts of other nationalities. Interest is keen in heuristic programming and its various potential applications. Automized summarization of texts in Czech and in Bulgarian languages has been achieved; French and Russian are now being attempted. Up to 80% reduction on scientific articles is possible. A joint Bulgarian-USSR enterprise in organizational design is underway.

Japan (Mr. Nishino). It appears obvious that to make progress in artificial intelligence research a major commitment of manpower and finances is indispensible. Once scientists managed to state clear objectives, the Japanese government has been willing to fund research aimed at achieving an information processing system. This funding is at a level of approximately $100 million dollars a year over an eight year period.

USSR (Mr. Butrimenko). There is a vast amount of activity at present. A recent AI conference was attended by two hundred workers. In Mr. Butrimenko's opinion, work in semantics is most relevant to IIASA needs and interests. IIASA should concentrate on specific semantic problems rather than organize research on a theoretical basis. Progress should come from within projects aiming at fulfilling practical tasks.

Mr. Butrimenko described work in problem solving that began with psychological study of humans and animals involved in finding solutions. The data was subsequently conveyed to mathematicians and computer experts who are attempting to simulate the observed behavior in models.

Advanced research is trying to comprehend the methods and activities of the brain with reference to vision and to hearing.

Robotics specialists are currently aspiring to simulate the movement of human beings and animals. Further experiments concerned the measurement of intelligence through processing of information and the synthesis of speech through pattern recognition. Personally, Mr. Butrimenko doubted that pattern recognition was a field that it would reward IIASA to enter.

USSR (Mr. Glushkov). Mr. Glushkov thought references to automatic theorem proving which delegates had been made premature. Perhaps computer-aided theorem proving might soon be possible. The Institute of Cybernetics is actively dealing with models of human personality, hoping to raise the level of hardware intelligence. Mr. Glushkov said that his feelings about AI in relation to IIASA projects and goals were consistent with the views expressed in the document contributed by the Soviet delegation for conference consideration (Research Project on Artificial Intelligence--Document B).

A delegate in support of the proposal commented that he found that the description of interest in semantic study needed specification. Might it not be tied in with work on question-answering systems? (Numerous research groups involved in classification tasks had been balked by the absence of any language enabling them to make semantic associations.)

Canada (Mr. Florian). AI work in Canada is fragmented, and research depends upon government finances. The youth of computer sciences rather than a conscious decision against the field helps to explain official stance. No critical mass of talented people exists yet to promote hopes of short horizon achievement, and government policy favors practical goals. Perhaps the ongoing project of greatest interest to IIASA is in the field of operations research where badly behaved programs are being subjected to investigation.

Hungary (Non-member country. Presented by Mr. Sandori.). Evaluation of electrocardiograms has been part of pattern recognition work designed and implemented with the cooperation of a hospital. Hungarian experience here is relevant to similar programs referred to during the conference.

Evaluation of bubble chamber photographs the basis of other experimental work is designed to reduce time required to perform input operations on computers.

Interlude: Discussion of Value of Predicate Calculus

In defense of predicate calculus a delegate said the language is adequate for all purposes contingent upon what kinds of entities are admitted and what formalizations are made. Doubts were expressed--is there not a kind of reasoning not possible in predicate calculus which involves making presumptions? Can pc minimalize, exclude? A major difficulty with pc is to secure inferences, deductions, aspects of language not merely implied in a sentence but stored in memory. How to describe not only grammatical relations but semantical relations is another issue. Case Grammar attempts to include with equivalent formalization sentences identified as alike intuitively. Another delegate added that the power of language was unlike predicate calculus; it did impose upon an individual the constraint of absolute consistency. A practical drawback of pc was adduced: mathematicians and scientists do not use it to write proofs with because such proofs are far too long. Yet, the conference was alerted that there is at present considerable energy being expended towards writing short proofs in predicate calculus--proofs nearly the same length as intuitive proofs--thus eliminating the many steps which have made pc cumbersome for scientists.

Interfacing of AI with IIASA Projects

At the conclusion of the national presentations, Mr. Raiffa attempted to present aspects of the IIASA projects in Medical Systems, Design and Management of Organizations, and Automated Control of Industrial Systems that would overlap with expressed interests in artificial intelligence.

1. The Medical conference divided its areas of concern in three: physiological processes, patient care, and public health. In studying what goes on inside the body the group aspires to looking at human existence as a system. There has been a spurt of such investigations recently and IIASA can function as a meaningful clearing house. It has been urged that IIASA do a feasibility study for a handbook of mathematical systems of physiology. In the area of patient care there is particular interest in biological engineering--the prolongation of life with artificial organs. Here technological advance has created particularly knotty decision making problems. It has been proposed that IIASA take a mechanical aid to the human system and look for systems implications of its use--a tentative project concerns computer-aided help for people with impaired vision. In the domain of public health the issue of dominant interest to the conference was the value of multi-phasic screening which has met with marked success in some lands and disillusioned its early supporters in others. An exhaustive exchange of experiences is indicated.

One participant said it hardly needs pointing out that any decision-oriented approach fuses the concepts of diagnosis and treatment. Some enthusiasm was manifested for using formal techniques--employing decision trees and decision analysis--in patient care. (Computer-aided techniques already exist for drawing decision trees with assistance of graphs and light pens.) Although such as approach with medical records and data banks may never provide a widespread basis for probability assessments--the procedure is far too expensive--analagous techniques might have a high payoff in developing countries. Mr. Raiffa was personally dubious but thought that the confidence of Minsky and Schwartz in the potential of AI in this area is almost contagious; certainly IIASA would consider study of promising areas of inquiry.

2. The project in Design and Management of Organizations is deeply concerned with the chasm between prescriptive and descriptive decision making. Work is in progress to translate understanding of cognitive behavior into formal prescriptive tasks. The use of fuzzy sets is relevant in this connection; the originator of the concept, L. Zadeh, is coming to IIASA in summer 1974.

3. In the area of Automated Control of Industrial Systems, operations research and management science are now grappling with job shop scheduling problems with stochastic inputs--an area which a delegate promptly noted has importance for patient care and public health as well. Such scheduling problems are easily described mathematically but hopeless to analyze, and algorithms fail. Heuristic procedures have demonstrated their serviceability here. Experienced managers do well at intricate scheduling. IIASA could study how we can learn from them, and how we can learn to optimize within constraints and apply the lesson to systems problems.

On a note of guarded levity, a delegate inquired if perhaps IIASA might not more profitably probe Natural Stupidity than Artificial Intelligence. Explication disclosed the seriousness of the statement: How is it still possible that major scale disasters of mismanagements occur, criminal waste, loss of life on an international level? What is missing in control of situations? How do systems break down? These questions might constitute a valuable territory for inquiry; there is a need for an independent, intelligent body to analyze the vagaries of human frailty.

Mr. Raiffa responded that "natural stupidities" was raised as topic of interest in several conferences, and was discussed at length in the conference on Design and Management of Organizations. Few countries feel secure enough to tolerate exposing their mistakes for general edification; most prefer issuing invitations to scrutinize their successes.

Within a context of praise men most readily accept suggestions for improvement.

Mr. Glushkov sought to elicit further responses to the Soviet proposal on artificial intelligence. Favorable comments expressed interest in semantic problems.

Modelling and Control of Information Flow in Living Systems

The difficulty of acquiring data is apparently responsible for ventures in this area. A delegate referred to futile attempts to study information processes linking the retina to the brain. Delegates felt that a conference on how to study brain activities from all points of view would not be feasible in the near future.

The delegates briefly discussed possible areas of biological studies where use of computer sciences might be helpful. These included:

- use of systems methods to describe organisms
- study of genetic information flow in DNA and RNA
- study of cell differentiation
- study of interacting automata (cellular).

The discussion became a rallying of voices in favor of IIASA's adopting a practical problem-oriented approach to artificial intelligence enterprises. Applied work on genetics was characterized as making demands IIASA is not in a position to meet.

Information Processes Inside Computers

A delegate introduced the subject of information flow "beneath the skin" of a computer. Difficulties in discussing this subject arise from realities of the competitive computer industry. One delegate alluded to a conference under the auspices of NATO which grappled with optimizing the operation of computers.

A delegate from one of the non-market countries reported ongoing efforts to optimize computer control which focused on the computer as a system. All operational software regrettably is made on a basis of art, not science. Applying systems analysis to software has already improved the efficiency of certain hardware by as much as 25%. The delegate wished to see IIASA undertake the laying of a fundamental theoretical groundwork for improving hardware efficiency and for designing optimal software. This idea was expanded upon by another delegate who considered it a good, practical, long term idea to apply systems analysis to computer use and optimization of computer control.

Mr. Capriz pointed out that to be considered in a meaningful way, the problem of optimal control related to computer design must involve researchers in building computers--this is not for IIASA.

In the interests of dispelling confusion a delegate explained that he thought two issues under discussion were not distinctly enough differentiated. One amounted to networking, i.e. how to distribute computer power. The other concerned optimization of an individual system.

Mr. Raiffa suggested that a systems analysis of a single computer which embraced the man-machine dimension was in effect a micro-version of analyzing a computer network. In the Design and Management of Organizations conference the problem of computer networking arose as well. One delegate cautioned that IIASA could not afford significant research into computer networking. ARBA-Net is currently under study with a yearly budget greater than IIASA's total annual expenditure. It was proposed that IIASA might examine external systems aspects of networking: How to cross borders? How to bring technology to developing lands?

A delegate expressed interest in ascertaining the time in the future when, for a reasonable price, everyone will have access to information of his choice.

Computer Applications in Information Transfer

Mr. Page introduced a proposal (Document R) dealing with information transfer--a concrete computer application project with systems analysis content of interest to IIASA. Forecasts are common of the world's choking on paper, of computers strangling on data. The information explosion denotes a situation where the output of useful items from research has exponential growth. Is it practical at present to restrict flow of information and still achieve useful information transfer? In teh past when natural sciences were virtually closed shops, it was possible for dedicated individuals to keep up. Now no scientist can afford the luxury of isolation within his chosen discipline. It might be said with only slight exaggeration, applied systems analysis must be interdisciplinary or it does not exist. Current computer files which are exclusively biology or applied math or statistics are grossly inadequate. IIASA's conference on Energy Systems, for example, has already revealed the dimensions of meaningful information need.

In a condensed history of computer evolution, Mr. Page described the provision of a body of sifted information as the earliest snag in organizing computerized information systems. Second generation computers and batch processing also proved unable to do the job--they either produced too much "noise"--irrelevancies through which users were unwilling to go wading--or filtered out too much useful information. The advent of third generation computers made direct access to a file of stored information possible, a research tool now in use for five or six years. These interactive systems, however, have proven to have their problems as well, especially the drawback of great expense. Storage costs are discouragingly high. Most systems as a result require multiple users to remain operational; a physical network thus exists as well as a computer-to-computer network. This is an additional hindrance to convenience and to efficiency.

It has before now dawned on many to apply systems analysis to information flow not merely on an ad hoc basis but to study user habits and needs and to learn how to meet these both economically and technically. Numerous groups are now learning how to do just that. IIASA should not compete or repeat, but help coordinate efforts.

In response to a question Mr. Page said he was interested in achieving a "factographic system," retrieving data rather than bibliographic help. He wants information on the output terminal, not information about information. Natural language retrieval systems are plagued with a variety of problems, but their overwhelming advantage is their ease for user. Natural language searching has been solved, for example, but natural language indexing not.

A delegate advised binding Mr. Page's proposal to IIASA's needs. A systems analysis of IIASA information requirements would be a valuable undertaking and could culminate in a concrete plan. Mr. Raiffa advocated an approach that attempted to combine research into the science of management information services in general and the implications of such services for IIASA.

After delegates commented that they knew of such work underway in several locations, Mr. Page stated that what concerned him and IIASA was that the various projects to improve particular systems--local, national, even international--were not integrated. IIASA might here demonstrate the importance of "banging heads together."

A study of ways to exchange information about information seemed to one delegate to be in demand. There was a reason to examine collecting systems and cross-referencing centers on a worldwide basis.

Mr. Raiffa repeated his concern with management's need for information collection, and suggested that IIASA might use a systems orientation to review existing information services and to determine if they are in fact collecting the "right" data. IIASA might endeavor to influence what sort of data gets sought--in many instances despite systematic information collection users and managers of surveys alike protest that they are presented with information that does not interest them. A project to design an information system within IIASA is necessary, but at present premature. Two experts from the USSR, Sumarokov and Trofimov, now counseling on the best ways to proceed.

Curiosity about the IIASA library expressed by delegates induced Mr. Raiffa to elaborate upon remarks which he had delivered at the opening of the conference. The breadth of applied systems analysis made any dream of an archival collection foolish. IIASA proposes to be at the hub of an efficient network to tie together the libraries of member nations. A collection of works on methodology and a limited selection of essential reading related to separate projects would be a feature of the in-house library. To date, the IIASA strategy of retaining librarians on the staffs of a variety of major libraries to speed information transfer in response to telexes has proven disappointly slow and freight costs high. An alternative tactic--hiring a full-time employee to maintain contact with major book distributors in London ordering and shipping books on a basis of a weekly IIASA requisition list--has revealed the drawbacks of relying on London too exclusively. On the other hand, Xeroxing from London libraries service is proceeding extremely well--a five day delivery time is possible. The cost of Xeroxing over telephone is prohibitive. The Institute will have microfiche readers and microfilm its own proceedings.

In response to the quandry of where to find relevant information quickly, Mr. Raiffa said that IIASA would avail itself of a far-reaching, exhaustive network of active scientists--people at the top of their field know what is going on.

Fourth Day

Automation of Design

Mr. Gavrilov presented his proposal (Document H) to the conference. The complexity and high labor consumption of design activities necessitates a full-fledged theory, software geared to this theory, and hardware suited to design procedures with their characteristically numerous criteria and uncertainty. Efficiency criteria have to be developed, constraints recognized, optimal designs sought. Yet, all design problems cannot be formalized. Man is an important element in any design procedure; the study and simulation of his behavior with a view to enhancing efficiency is a major component of the automated design problem.

The proposal has four aspects:

1) Systematic research of common features and models of design processes culminating in functional models of automated design, analysis of which will permit finding optimal structure for such systems;

2) Development of software for designing systems, in addition to arranging all solution algorithms for design problems;

3) Incorporation into software for design systems of an information sub-system of strong data required for designing; and

4) Development and study of two specific designing systems--one for scheduling and control of a developing process such as an expanding, re-constructing town, and one for design of dis-continuous units, i.e. one in which man-machine concerns are dominant.

Mr. Gavrilov emphasized that all phases of intense work would be performed by national member organizations and therefore would not be a problem for IIASA.

The main direction of interest in the field at present is in optimizing the design process with reference to a multi-dimensional space. The issue is of interest in many countries. A conference in Moscow months ago included a special section on theory of design. Here it was felt that work to date has not been particularly successful. Perhaps to use the word "theory" is somewhat presumptuous as the subject is so embryonic. Although it is not altogether certain that any general theory of design is possible, experience in research suggests it is. There are already several successful algorithms in the USSR for optimization of certain features.

Among the particular problems to which Mr. Gavrilov gave emphasis was the development of a dialogue system which would enable men to talk to machines and to receive answers in natural languages. Programming languages in use involves translation, a formalization of statements which excises variables, loses information, and consequently eliminates certain possible solutions. Since optimization is generally calculated on the basis of natural, not formal, languages, this introduces inconsistencies into the methodology.

Furthermore, feedback and control between the designer and the design process is essential in any design system. At the Institute of Psychology at Moscow University, a special laboratory is now investigating the creativity of the designer. Some experts are skeptical about attempts to incorporate problems of psychological nature into design research, but useful work in developing methods (e.g. dialogue systems) suggests this avenue merits further exploration.

An advantage of his proposal, Mr. Gavrilov explained to the conference, was the number of regards in which it overlapped proposed IIASA research areas. The first step in the undertaking would be to write an international review on the state of problems of systems analysis in conjunction with design. This might require two years.

One delegate asked what was meant by the term, "design activity," was it a process which ended with the drafting and presentation of a blueprint. In response Mr. Gavrilov stressed the continuing nature of the process of design, the ongoing need for new data, the incorporation of new information, new parameters in the design. In planning an airfield it would clearly be folly to resort to the same body of data beginning to end without constant investigation, without provision for revising ideas.

Favorable discussion of the proposal followed. Minor objection was voiced to the schematic division of the proposal into four year-long stages since work in various phases would overlap. Are we, a delegate asked, in doing research into theory of design, to insist on design in its broadest signification, embracing ships and microparts of computers? Is this spectrum too wide? What began as something of a grumble changed tone in the course of delivery. Considering his words, the delegate declared that perhaps the inclusiveness could be valuable: if not at IIASA where else would ship designers and electronic part manufacturers come into contact and perceive common systems problems?

Another delegate amplified this idea. Design project would be an opportunity for IIASA to bring together people with different resources and perspectives--not necessarily from different nations but different technicians. It was his conviction that by demonstrating the value of such communication IIASA could exert an influence on many countries to convene similar meetings. Most national activity on design is attacking specific questions and is apt to lose perspective of systems aspects of such work.

A facet of the Automated Design proposal which particularly concerned one delegate was the organization of information systems to aid the designer. An acute problem for modern design projects which invariably involve the cooperation of many groups is how to manage voluminous data. Another delegate interjected that simply the documentation of many design projects presented nearly insuperable cost difficulties. Computer support might facilitate documentation.

Perhaps, a delegate thought, it would be best for IIASA to limit the area of investigation to study of design principles of manufactured goods--one would study an industrial production system which turns out a large variety and number of goods. Another delegate, however, argued that the design of public interest projects--one shot affairs never repeated--seems more pertinent for IIASA.

Mr. Capriz suggested commencing with compilation of a review, relying on collaboration of member institutions. The initial necessity is to explore the availability of willing expert personnel--at the very least as correspondents. At the beginning a few in-house people would be needed to crystallize ideas. They would be neither project directors not secretaries but individuals devoting themselves for several months to the subject and pondering the payoff of going further.

Mr. Raiffa was pleased that the conference thought the morass of automated design was tempting enough to test the water with a preliminary toe. He called for written suggestions of high level consultants to approach.

Mr. Gavrilov concluded discussion by remarking that he took encouragement from the positive tenor of delegates' responses. Organization of the project in IIASA must be done carefully. Compiling a review would present less difficulty than beginning on a theory of design. It would be advisable to canvas member organizations about their experiences; they could perhaps propose strategies. Actual decisions about financial and human possibilities could follow.

Mr. Raiffa agreed and noted that experience had taught him the value of definite, structured questionnaires. He invited the USSR to draft a questionnaire that could be tested for usefulness in one or two countries, and then sent out to member nations.

Concluding Discussion

Mr. Capriz reminded delegates of general areas of discussion during the conference. In reference to computer services he expressed the group's concern that careful specification of needs should precede investment in major hardware. Present requirements are apparently limited and can be accommodated by admirable in-house facilities. Clearly, however, in the long run IIASA must tap many computer centers and tackle problems of interfacing.

Mr. Capriz thought the conference was interested in the proposal delivered by Mr. Glushkov. He alluded to promised cooperation with the resident IIASA forecasting expert. Mr. Raiffa added that forecasting is an appealing area of investigation for IIASA because so many projects stand to benefit appreciably from any progress in methodology. He termed the opportunity for cooperation with the Institute of Cybernetics fortunate.

Continuing his summarizing remarks, Mr. Capriz cited the interests of more than one delegate in research designed to place objective constraints on leadership by proving a particular policy is the best way to achieve stated goals. Relevant work in Chile of some significance prompted the co-chairman to suggest IIASA to invite Mr. Stafford Beer to record his results. While expressing his personal concern about moral responsibilities entailed in imposing structure on society with computers, Mr. Capriz thought the tenor of group sentiment opposed committing IIASA to any study of computer impact on society. This did not mean, however, that IIASA should not gather all available pertinent documents and perhaps sometime in the future convene not only scientists but also managers and politicians to discuss the issue.

Moving on to the topic of Artificial Intelligence, Mr. Capriz believed the conference was in tentative harmony that in engaging in any original research IIASA would be well-advised to advance gingerly. Immediate applications to systems analysis should dominate the choice of research direction. The USSR proposal on AI and a proposal written cooperatively by several delegates could represent conference opinion to the Council.

"Healthfully skeptical" was how the co-chairman described attitudes expressed towards projects concerned with the flow of information in live systems. Management of information systems in general and with relation to IIASA in particular was more germane to the Institute's future, especially for successful performance of IIASA's important sophisticated clearinghouse function.

Mr. Glushkov commented that the forecasting work he described earlier included a significant social impact dimension. There followed an eleventh hour outbreak of interest in conferences about computers.

A delegate recounted how an international conference last year in Washington, D.C., about the computer and the future, flopped dismally because there was no interaction between sociologists and technologists. A weeklong conference sponsored by Olivetti was termed successful. A gathering of engineers, mathematicians, economists, and sociologists collectively discussed good ideas ranging from definition of rationality to the possibility of foreign policy dictated solely by applied systems analysis. A conference in San Francisco about computers and health care delivery ended without opposing camps of socio-economists and technologists ever entering "no man's land" together. The conference might have succeeded if sociologists and technologists had been previously paired to prepare papers.

Mr. Raiffa considered news of many unsuccessful efforts to organize a first rate conference as confirmation of the interdisciplinary challenge awaiting IIASA. Mr. Glushkov described experiences at conferences fully consistent with other reports. He said that conferences must focus on a small, specific issue and gather people with a variety of outlooks. He explained that research is now under way on how to carry on a debate between a mathematician and a sociologist within the entrails of a computer which would at length disgorge not a compromise opinion but a synthesis of the best thinking of both participants. Perhaps the program would be operative within a year or two--such a machine would be an impressive delegate at a IIASA conference!

Final discussion recapitulated urgent interest in real· problems connected with implementation of international computer networking. It was proposed that study of prospects of linking east-west lines across Europe should commence with IIASA perhaps attempting to coordinate present activities of the European Community and various postal-communication systems at work on the problem. Mr. Raiffa remarked this conformed with general IIASA strategy to identify groups working in a particular area and to find out if IIASA can be of help. Often organizations and committees baffled by the weight of their own bureaucracy and entangled in difficult concrete problems welcome the advent of a person or group in a position to analyze the situation from a distance. He expressed particular interest in a network project which might produce information or strategies helpful to the developing world.

Mr. Klix read to the conference a proposal containing the amalgamated views of several delegates (Document C). The paper emphasized the importance of IIASA's approaching artificial intelligence research initially from a standpoint of work in languages. Semantics is the key. As a spokesman for the USSR delegation, Mr. Butrimenko explained that the new proposal in effect superseded the USSR document submitted earlier. A delegate suggested that initial dedication to semantics would temporarily relieve IIASA from hurrying to acquire major computer machinery. Perhaps in a year technical advance might enable a basic "number crunching" facility like the CYBER 73-74 to provide rapid, interactive service. Mr. Glushkov expressed his conviction that a mini computer in Laxenburg would, beyond its function as a real time concentrator, be valuable for resident scientists who will require a terminal through which to access large installations elsewhere.

On behalf of the conference, a delegate thanked the co-chairmen, Mr. Raiffa, and the IIASA staff for all they had done, and the conference adjourned.

I. PAPERS, PROPOSALS, AND COMMENTS

Document A

Michigan Terminal System and SIMCON

S. Borden

MTS

MTS (Michigan Terminal System) is an operating system for the IBM 360/67 which was designed at the University of Michigan and which is used at least at The University of British Columbia, The University of Alberta, The University of Michigan, and University of Newcastle-upon-Tyne. It is a time-sharing system which uses the dynamic address translation of the IBM 360/67. There is an extensive collection of language translators including FORTRAN, ALGOL, PL I, APL, LISP, SNOBAL, PLC, ALGOLW, BCPL. There is an excellent terminal-oriented text editing system and a number of text formating programs.

SIMCON

SIMCON is simulation control command language which was designed and programmed at the University of British Columbia by Ray Hilborn. Basically, the program:

a) calls a subroutine which performs the necessary transformations on the models variables once for each time step;

b) produces plots of selected variables during simulation;

c) allows intervention at any time; and

d) plots any set variables at the end of a simulation.

Document B

Research Project on "Artificial Intelligence"

A. Butrimenko

I. Introduction

We would not like to start the discussion with the terminological debate. We would now like to avoid determining the subject "Artificial Intelligence" and will understand this field as it is formed in the world scientific literature.

This vigorously developing field includes the following:

1. The study of the methods which are used by human beings for problem solving.

2. The design of the technical devices which could substitute completely or partly a human being while solving hardly formalized problems.

3. The problem of the designing of special technical devices --robots which can act relatively autonomously and have together with a solving system a set of receptor and effector systems. These two kinds of systems enable the robot to communicate with the outside world.

The aim of the project is not to create a theory of "Artificial Intelligence," but rather to systematize already obtained knowledge and to develop some themes which seem to be cardinal for this field.

Artificially created intelligence in the real sense of the word has to include in itself a number of different systems, specially designed for various functional purposes. We do not think, of course, that it is possible to create such complete intelligence during the next decades. In our time it is useful to concentrate our efforts on creating so-called partial intelligences which are relatively simple to realize and at the same time are of great practical significance.

A partial intelligence can substitute for human beings in special professional activity.

To develop systems of that kind it is necessary according to N.J. Nilson to use the following disciplines: "mathematical logic, computational linguistics, theory of computation, information structures, control theory, statistical classification theory, graph theory, and theory of heuristic search." It is reasonable to distinguish three groups of aims and problems.

To the first group belong the problems which can be solved by the creation of more or less complicated software. We mean the activities of a human being which are connected with the solving of problems which cannot be completely formalized and about which all the information is sometimes unavailable.

To those partial intelligence belongs the artificial intelligence of an astronaut, physician, meteorologist and others.

It is very likely that some problems which now seem to be the problem of artificial intelligence will--owing to their higher degree of formalization--later be considered as problems which can be solved with the help of standard mathematical methods.

The performance of the second group of tasks can be achieved by the designing of special devices--robots which can substitute for a human being in his activity in unfavourable environment or in his carrying out of monotonous works. The talk is about the second and third generations of robots and so-called integrated robots.

The designing of such robots is needed because of growing costs of toil and permanently growing interest of mankind in the activities in unfavorable or hostile environments. First of all we would like to mention underwater and space research.

Finally the third group is connected with problems of studying human being behavior while problem solving as well as with preprocessing in receptive systems (sight, hearing, sense of smell and so on.) The study of these processes which is very useful, for designing of technical devices is of great importance for sociology, psychology, physiology, and medicine.

II. Research Program for the Project "Artificial Intelligence"

We do not underestimate the importance of the second and third group of problems, but we think it would be expedient to concentrate the main activity inside IIASA on the problems of the first group. The reason is that the solving of the problems of the two last groups would be incomplete without some kind of experimental research. To carry out projects which are connected with designing or even only using hardware (except of computers) would be unpractical in this Institute.

Therefore we suggest restricting activities in the second and third group only to study and systematization of the already achieved result. On the other hand it would be wrong to ignore completely these branches. We will very likely get here new, fundamental results which will force us to correct our views on the artificial intelligence problems.

Besides, the development of the robototechnique is of a great importance for the whole mankind and in the first place economically developed countries. Timely information on trends in robototechnique will be useful for all member states of the IIASA.

Let us consider more closely the problems of the first group--the problems of the functional substitution of a human being in the decision making chess example bring about some difficulties. As Minsky says: "It is not that games and mathematical problems are chosen because they are clear and simple; rather it is that they give us, for the smallest initial structures, the greatest complexity, so that one can engage some really formidable situation after relatively minimal diversion into programming."

Numerous chess playing programs have been written, but nevertheless up to now the results are not large. Why is it so? In our opinion the reason is the wrong psychological conception which is the basis of all these programs and, as the consequence of this, the use of unsuitable mathematical methods.

All these programs are more or less based on the search in a labyrinth. We believe a human being can perform this task effectively by rejecting unpromising variants.

The programs are developed such that the variants (branches) must be estimated and rejected or accepted. Unfortunately, in cases which are of interest--such as chess--the number of variants is so tremendous that the computer cannot compete with middle level chess-player.

Psychologists give us some useful hints. They say that during the creative activity there is no preformed labyrinth. The substance of the creative activity is just to create a part of labyrinth which includes in itself the way to the goal. This is possible only if the individual (or robot) has the ability for systems analysis of the problem, the ability for finding in it the main concepts and relations between them, the ability to form the structure of the initial information and to transform this information into a model of semiotical kind.

There are always two stages in the problem solving of the control system:

1. The stage of creating a more or less formal model.

2. The stage of solving and decision making on the basis of the created model.

The classical control theory deals with the second stage. The first one was considered as unformalizable. If the second stage thanks to its formalization has been developed and can be treated with the help of a computer, the first one depends up to now on the natural intelligence of the engineer.

The methods which can be used in the second stage depend on the mathematical formalization of the model. Unfortunately, when we want to create a formal model which uses a human being driving car, playing chess, or controlling chemical processes, we can not get a mathematical model because a human being does not formalize it in a mathematical way. For this reason the problem of creating a model on the basis of a human being's experience brings us to some semiotical models.

We believe that the development of the semiotical models is a cardinal theme which determines the development of the whole field of artificial intelligence.

As every new theory which has no clearly stated problems, it must begin with solving some concrete tasks. It allows us to concentrate the theory development on the direction useful for practical tasks.

We think that activity on the project "Artificial Intelligence" must be based on the development of some models for practical tasks.

We would like to propose the following tasks:

1. To develop the model of the dispatcher (controller) and his outside world. This model can be concretized

   - for air traffic control within the region of a large airport,

   - for control of multi-line conveyor system at the engineering plant, and

   - for management of loading and unloading ships in a large seaport.

Similar problems arise while developing operational systems for complicated geographically distributed computer communication systems, and while organizing certain management systems, and so on.

2. To draw up a research plan.

Document C

Remarks Concerning Artificial Intelligence Activities in IIASA

A. Butrimenko, F. Klix, J. McCarthy

The reports of national representation have shown that AI is a broad and interdisciplinary field. Nevertheless there are strong activities in nearly all member countries.

It is generally agreed in AI that the biggest current problem is to define what information an intelligent entity needs to know about the world and how to represent this information in the computer. It appears that interest in this question exists in the USA, GDR, and USSR, but there is little present contact between eastern and western work in these subjects. Moreover, questions of semantics arise wherever question answering based on a data blank is considered. The problem is important for handling the following tasks:

1. Medical care systems
2. Economical and management systems
3. Question answering systems
4. Automated design systems.

Practically we propose the following activities in IIASA. We suggest a study at IIASA with representatives of both areas on semantics connected with question answering systems from data banks. We further suggest that this study consider the practical questions of how to get a uniform method of access to information in remotely accessible computer data banks.

Such a system might be constructed at IIASA and would have the following components:

1) The system is a program in a suitable time-shared computer at IIASA or used heavily by IIASA.

2) The program provides a uniform method of asking questions, decides what data bank has the information needed, automatically connects to the data bank, makes requests to the data bank in the required form, and presents the answers to the user in its standard form.

3) The scientific problem of designing such a system requires interesting research in the semantic part of artificial intelligence and in computer system pro-

gramming. Moreover such a system will be useful to the other disciplines represented at IIASA and to other scientists that may have remote access to a suitable IIASA computer. Finally, the concrete problem and its related theoretical problems have a common interest.

Document D

Brief Remarks about IIASA and Computer Science

J.M. Cadiou

It seems to me that the various interactions between IIASA and computer science can be organized along two broad questions:

1) What can Applied Systems Analysis do for Computer Science? and

2) What can Computer Science do for Applied Systems Analysis?

1. What can ASA do for Computer Science?

1.1 For one thing, computer systems are complex systems, and therefore can be considered as a potential subject for Applied Systems Analysis. Evaluating, modelling and predicting the behavior of Computer Systems is therefore relevant to IIASA. There has been a considerable amount of work in that area, both in the academic and industrial communities. Yet much remains to be done, and it seems that significant progress could be achieved by bringing together people of different disciplines (statistics and computer science for instance). Certainly a substantial amount of what will be done in the Global Simulation and Modelling project should be of use here.

1.2 The question of the planning of computer facilities for a given firm, institution or community is also relevant to ASA. Until recently much of this was more or less left to the computer manufacturers, the users being for the most part in a position of inferiority. More and more software consultants are now undertaking to give independant advice on these matters but yet it seems that this field is a choice area for applying ASA techniques, and that the Institute could contribute to it.

1.3 Computer networks are now developing and it seems that IIASA should have an important role in this area, at least in two different ways:

- first by applying ASA techniques to computer networks considered as systems,

- but also by investigating the feasibilities of establishing a computer network including computer centres of the western world as well as of the socialist countries.

1.4 Another relevant area which perhaps belongs here is the fundamental question of the relationship between computers and man, more precisely the study of the impact of computers on society. It seems that somehow IIASA should get involved in that field, either globally, or by examining some aspect of it in detail, such as:

a) the limitations to individual privacy which the computer era seems to bring about.

b) How can computers be used most efficiently to help solve some of the problems in developing countries.

2. What Can Computer Science Do for ASA ?

2.1 First of all, computers can obviously carry out computations which would otherwise not be practical, and thus considerably expand ASA's possibilities. Along those lines, IIASA should develop an interest for relevant packages: numerical, statistical, modelling, simulation etc. Perhaps it would be in order for IIASA to gather information about such existing packages, as well as detect the need for better ones and facilitate their undertaking.

2.2 More specifically, the use of computers in simulation and modelling is of prime importance to ASA. Several projects of IIASA might find that they have common needs in that area, and that it is worthwhile to undertake or facilitate an effort to promote better languages or systems for simulation and/or modelling. It is my opinion that this should be basically "user oriented."

2.3 Data bases and information retrieval systems are also of prime importance to IIASA. Even more so since one of IIASA's role should be to facilitate communications and information sharing between various people.

2.4 Computer systems have now become sophisticated enough so that they can provide a variety of services which can considerably increase the productivity of the various people involved in a project. For example, computers can help maintain and update the documents produced by a design project. They can also facilitate communication between the various persons of projects as well as between the project and the outside. These and related concepts are rapidly developing in many advanced computer research projects but could conceivably expand to a number of other projects as well, both in public administration and in the industry. IIASA's interest in methodology should incorporate these ideas as well.

2.5 A rapidly growing field of interest in computer science is the so-called "Analysis of Algorithms" area. The problems tackled are of two kinds:

(a) mathematically evaluating the performance of an algorithm, essentially in order to compare various algorithms to solve a given problem, and

(b) finding "best" algorithms for solving a class of problems.

The techniques used in this field mainly draw from combinatorics, probability theory, graph theory, discrete mathematics. These techniques could presumably apply to various problems and algorithms in operations Research and related fields. IIASA would be in an ideal position to bring people from the Analysis of Algorithms area together with people from the Operations Research area to work in this field.

Document E

Position Paper

Representatives of Canadian Committee for IIASA

The following is a summary of the conclusions reached at a meeting on Computer Systems convened by the Canadian Committee for the IIASA.

- There was general agreement that provision of computer support by purchase was not desirable, in particular for the early stages of development of the Institute.

- The meeting agreed that the research theme "Artificial Intelligence" was not considered to be of immediate concern to Canada, since there was little current national activity in this area. However, in view of the potential future interest, proposals advanced by others would be welcome.

- It is recommended that the Institute maintain flexibility in its choice of computer service and support and to this end:

  (i) rely on a small but competent staff of computer analyst/programmers,

  (ii) establish means of utilizing local computer resources,

  (iii) purchase several low speed and possibly one high speed terminal that would permit access via international/national communication lines to large computer centers,

  (iv) investigate costs and commercial arrangements for such service, since these represent a major element of costs in such computer support.

- It is recommended that the Institute consider application of a mini computer for use in off-line operations and for on-line applications as a means of interfacing with the remote computer centers.

- There was general agreement that software development priorities should be in response to the needs of specific projects.

- The meeting noted that the approach suggested was probably the only practical course in view of the total budget that the Institute has available for computer support.

References

IIASA/DIR/R/5	- Schedule of Symposia
IIASA/RES/P/5	- An Initial Research Strategy for IIASA
IIASA/DIR/G/1(PROV)	- Background Information Provisional Research Strategy
IIASA/DIR/M/1	- Report on Meeting on Library Facilities
IIASA/DIR/M/2	- Report on Meeting on Computer Facilities
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Document F

Artificial Intelligence and Advanced Automation*

Jerome A. Feldman and Richard Paul

Artificial Intelligence (AI) is the study of the acquisition, representation, and use of knowledge. The scientific aims of the discipline are to understand these issues in general and to provide the basis for various applications. The contributions of AI to advanced automation fall into three broad categories: perception, manipulation, and problem-solving. We will discuss each of these in turn, providing cross references to other background areas and to a selection of papers from AI Conference of August, 1973.

1. Perception

Research on machine perception has been an important part of AI for a decade. Most of the work has been on vision, but there has been significant effort devoted to touch and force perception. The work has been less concerned with sensors than with the information processing required to understand the real world. Major research topics in vision include edge-detection and region-growing (ref Feature Extraction), picture parsing, and model based scene analysis. Significant additional topics include depth perception, color and texture analysis, and special purpose vision techniques such as template matching. The major current trends in vision research are a) incorporating problem-solving techniques into vision systems [2] b) rigorous analysis of scenes of simple curved objects [1] and c) partitioning and labelling of arbitrary scenes [7]. This last area is concerned with two-dimensional images and seems immediately applicable to medical automation tasks.

Much of the early work on vision was concerned with scenes of blocks; this problem is now quite well understood and work on more complex objects is advancing. However, for the next few years, it will not be possible to apply general vision programs directly to most assembly and inspection routines for use in these tasks. There is also increasingly sophisticated usage of touch, force, and other sensory information in assembly tasks. Visual feedback control of manipulators is another important research topic. There are a number of prototype systems [2] which can assemble and inspect objects of a dozen or so parts, such as an automobile water pump. Within a year or two, it will be possible to assemble objects of a hundred parts with very few special purpose jigs or tools. The problem of programming such tasks is a crucial issue and is discussed

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*This paper was originally prepared for the Automation Research Council, U.S.A.

in Section 3.

One important problem in applying vision to automation tasks is representation [1]. Any visual perception is based on a view of only part of a scene; the missing information must be inferred from an internal model of the objects involved. The problem of representation of objects is also important for other aspects of automated assembly.

2. Manipulation

AI research in manipulation was started in order to provide an effector system for a computer. Manipulators were available in one of three forms: industrial, prosthetic, or teleoperator. These available forms of manipulators were the basis for initial work but their unsuitability for computer control soon led to the development of special manipulators for this purpose [3].

Initial work by Ernst in 1961 involved the use of touch feedback and was highly interactive with the environment; however, with the advent of computer vision the arm became a simple effector relying entirely on vision for sensory input. During this time, manipulator work was usually restricted to connecting a manipulator to the computer such that control of position could be obtained, and to writing programs which would convert from spatial position to joint variables. The manipulator was moved from position to position defined by the vision system. The problem of moving the manipulator through a space with many objects was also studied.

Recently, tasks requiring more complicated manipulator control, such as inserting parts and screwing in screws were attempted [2]. In these tasks force feedback is necessary and is obtained either by controlling the manipulator drive or by measuring the forces at the wrist. In tasks such as grasping objects the use of touch provides for much better control than vision. Final positioning of the hand is usually done by means of touch.

Arms with these types of sensory inputs exist and programs for controlling them have been written [5]. The sensors at present leave much to be desired, but with development this problem can be solved.

Programming systems exist which divide a task into a planning and an execution phase. The planning phase runs under time sharing and makes use of all available information. The execution phase is a small program designed to run on a minicomputer and is capable of executing a planned program repeatedly. The key problem in manipulation is the ease with which a manipulator can be re-programmed. Extensive development of manipulation languages is in progress, and new systems will include the simultaneous control of more than one arm.

3. Problem Solving

One of the central concerns of Artificial Intelligence is the study of how complex problems are solved. This has been studied in a wide variety of symbolic domains such as game playing, theorem proving, and management decision making. Many of the early results of this research are in standard use in systems for resource scheduling, pattern layout, investment management, etc. As computers become more prominent in the manufacturing process, these techniques will be extended as a natural part of the process.

A more recent, and much more important, line of research concerns problem solving in a real-world environment involving perception and manipulation [2, 6]. Many new problems arise in actual rather than symbolic interaction with the world. Much of the work on real world problem solving is based on hand-eye-computer systems and is directly related to automation. The most important application is to the problem of programming advanced automation devices.

Even if we have perception and manipulation facilities for complex assembly, we will have to explain what needs to be done. It currently requires a sophisticated programmer to set up an operation. What is needed is a programming system which will figure out how to do a task from a description of what is to be done. This is an aspect of automatic programming, a subject of great current interest. In three to five years, there should be usable semi-automatic systems for instructing assembly devices. This will rely on advances in perception, representation and computer graphics as well as in automatic programming. We also expect further applications of AI techniques to medical decision making [7].

A related and important line of work is the development of systems support for complex devices [4, 5]. A typical installation will involve several devices and perhaps several computers working together on a task. The development on programming languages and operating systems for such situations is crucial to automation as well as a number of other applications.

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Document G

About Computers and Artificial Intelligence

G. Gatev

It is a good idea for IIASA to deal with:

1) computer networks. They are a very useful tool in dealing with complex system studies (modelling, optimization, etc.)

   I suggest that a conference be held on computer networks including topics of modelling of computer networks in the second half of 1974;

2) When considering computer facilities at IIASA, we have to take two things into account:

   a) the existing situation in member countries regarding working computers, and computer systems under development. Without this, there is a risk of diminution of information exchange and activities based on National Research Institutes;

   b) tendencies and perspectives of computer development.

      The question of optimal (compromise) choice of computer systems arises.

3) There is some doubt as to the use of the term artificial intelligence. There is a view that anything presented in an algorithmic way (formalized) cannot be called intelligence. If we adopt a working understanding that artificial intelligence is the use of new knowledge, then a simple, comprehensive illustration would be the updating and adaptation of models, based on incoming data from processes, used for example in industrial control systems.

Document H

Automation of Design
(Proposals on Future Activity of IIASA)

M. Gavrilov

Automation of design is a major research field which makes a significant contribution to technological progress because of the increasing complexity of plants and systems to be designed.

Despite differences in content, design processes have numerous common features. The research objective is to find these features so as to simulate and control design processes.

The complexity and high labor consumption in design activities necessitates a full-fledged theory, a software geared to this theory and hardware geared to design procedures with their numerous criteria and uncertainty. Efficiency criteria have to be developed, constraints recognized, and optimal designs sought for. All design problems cannot be formalized. Therefore, a man is an important element in any design procedure, and studying and simulation of his activities with a view to enhancing the efficiency is a major component of this problem.

The various problems arising in automated design activities can be classified into four groups. The first is systems research of common features and models of design processes. The experience accumulated in development of automated design systems could be studied, and the specific and common features of various design processes in different areas could be identified.

Socio-economic factors such as economic indices, state-of-art in science and technology which affect the selection of major and promising directions in design and psychological and social factors are very important in setting up designing systems.

Large-scale designs involve numerous personnel, making decisions at various levels. The implications of these decisions are quite different. Many of them seem to be automatable provided that artificial intelligence is in-built into designing systems.

Research in this field should culminate in functional models of automated design; analysis of these would permit finding an optimal structure for such systems.

Another field is development of software for designing systems. Problems facing a designer are different from those that have been thoroughly studied in the classical theory. These as a rule are optimization problems with numerous criteria, very high uncertainty of the source data, and logical variables. Experimentation or test of prototypes plays a significant part in designing. Effective experimentation with its high cost and constrained duration remains an unresolved problem.

Human decisions are very important in designing. The design process is, however, so involved that some of its specifics tend to be overlooked. Effective man-computer interface may prove very helpful here.

This is a very incomplete list of problems which require development of appropriate solution algorithms.

A designing system cannot, however, consist of manuals on the solution of individual problems. These manuals should be rearranged into program packages for digital or hybrid computers with all necessary peripherals.

Therefore, still another field of research should be the development of software for design systems, including the architecture which is a major variable in convenience and, consequently, efficiency.

In addition to arranging all solution algorithms for design problems as programs, this system should incorporate an information subsystem strong data required for designing.

A final area of research is development and study of two specific designing systems. Of these one is designing a system for scheduling and control of a developing process such as an expanding and reconstructing town. The other is a system for design of discontinuous units. These two systems are not selected at random. In the former the most important part of the plant is teams of people interacting with the economic system. In the other system the plant is purely technological. It seems evident that in these two cases the designing systems should be based on quite different principles.

A detailed description of the proposed themes of research is given in the appendix.

The research along these lines will presumably be completed within 1974-78 and therefore can be conveniently divided into four stages.

The first stage will be devoted to a systems study of features common to all design processes. A profound analysis of the state-of-art should be performed at various levels; the common features, specifics and problems arising in designing systems should be identified and formulated.

These activities should culminate in an international survey to be published in 1974.

The second stage will be development of algorithmical procedures. Effective procedures and algorithms should be developed for the solution of multi-criterion design problems, optimization in discrete spaces, and compativiluty and assembly problems. These activities should be completed by 1976. It is desirable to publish the intermediate results in a yearbook of IIASA papers.

The activities of the third stage, on program packages, should run in parallel with the second stage and culminate in program libraries in design-oriented languages. These activities should be completed by mid - 1977.

The final stage will be completely devoted to development of specific designing systems as specified above and result in complete software for these systems.

All these activities should be performed chiefly by national organizations.

A permanent team of twelve to fourteen should be deployed in IIASA, of whom six or seven will be scientists and the others, technical personnel. The chief task of this team will be coordination.

For a period of two to three months this team may be supplemented with a desirably international group of five to seven scientists who will work on a major part of the overall area.

For effective exchange of information, workshops on specific problems may be held twice or three times a year either in IIASA or in management national organizations.

Scientific management should be ensured by a leader and his two deputies, desirably from different countries, who should meet in IIASA at least twice a year to discuss the status and identification of problems where the main attention should be focused.

These activities will require much computing time to be made available chiefly by national institutions, but the IIASA computer center should provide about 60 hours monthly.

To discuss the results before a wide audience, it is desirable to hold two IIASA-sponsored conferences in the first quarter of 1975 and in the first quarter of 1978 and to publish a monograph on design theory and its application by late 1978.

Appendix

List of Research Topics on Design Automation, 1974-78

1. Common features and models of design processes

   1.1. Socio-economic factors of design

   1.2. A man and artificial intelligence in designing systems

   1.3. Dataware of designing systems

   1.4. Uncertainty in and estimation of the state-of-art in a designing system

   1.5. Functional models of designing systems

   1.6. Forecast of new design solutions

2. Development of design methods and algorithms

   2.1. Development of methods and algorithms for search for optimal design solution in multi-criterion problems

   2.2. Development of methods and computing algorithms for optimization and multidimensional discrete space

   2.3. Development of methods and algorithms for planning of controlled experiments with a vectorial performance index and constraints on cost and duration

   2.4. Development of arrangement and assembly optimization for plants being designed

   2.5. Development of effective man-computer procedures in development of design solutions

3. Languages and data retrieval systems in design

   3.1. Principles and architecture of a language for description of combined batch continuous plants

   3.2. Principles and architecture of a language for description of digital automated plants

   3.3. Architecture principles for data retrieval systems to store, update, process, and read out data required for design

4. Development and study of specific design systems

   4.1. Design of a town development planning and management system

   4.2. Design of discrete units

Document I

Computers and Systems: Proposals for IIASA

V.M. Glushkov and O.I. Aven

The increasing importance of computers necessitates inclusion of computer technology in the scope of IIASA activities. Practically no systems analysis problem of any magnitude can be solved without electronic computation. Computers strongly affect technological systems, and largely dictate the operating procedures and structures of the management systems. Finally, a modern computer is itself a complex large system, one of today's most complicated technical systems. This complication will increase with sophistication of computers and expansion of their potential.

Activities in computer support of IIASA projects can be divided into two groups:

1) Hardware selection and operation.

2) Development of special-purpose software.

One feature of IIASA projects is their variety and interdisciplinary nature. Therefore the needs in computer hardware and software will change constantly or at least periodically. At present it is hard to specify the kind and potential of computer facilities. The specifics of IIASA, however, clearly indicate the need in a special service to study the present-day and future needs of IIASA in hardware and software. This can only be done by specialists, well-versed in computer facilities and well-informed of new trends in their development. On the other hand, these specialists should be able to estimate, analyze, and forecast the needs of each IIASA project. They should provide sound initial data for management decision on IIASA policy in the computer field. These activities are undoubtedly scientific in nature and therefore specialists involved must be highly skilled scientists.

Consequently, one or two experts must be assigned to work within the framework of a larger project on "Computers and Systems."

As will be shown below, these activities are inseparable from other studies in computing technology to be carried out in the IIASA. This is especially true of software. Again, the variety of IIASA projects will require most diverse problem-oriented software. Furthermore, development of special-purpose software would be useless and frequently impossible because the leading scientists will stay in IIASA only for brief periods, and therefore most studies must be completed within that time. On the other hand, research institutions in various countries have accumulated numerous programs to solve specific system analysis problems and further programs are forthcoming.

It seems advisable to organize the research along the following directions:

1) Cataloguing the software potentially useful for the IIASA.

2) Contacting other organizations to borrow or hire their systems analysis programs.

3) Ways to obtain such programs from scientific and industrial organizations in various countries.

4) Estimation and forecast of IIASA software requirements.

5) Storing and filing the special systems analysis oriented software.

6) Whenever necessary, renovation and modification of software obtained from outside.

Software is understood as:

a) applied systems analysis programs and packages,

b) internal special-purpose programs for computation control, and

c) systems analysis models and algorithms.

Research in software is obviously related to the whole set of IIASA projects and implies knowledge of requirements of each project today and tomorrow. It also requires good knowledge of the state-of-art in systems analysis in many countries and especially of those studies that have been brought to the stage of models, algorithms and programs. Research in IIASA hardware is of discrete nature; the software research should thus be in contact both with IIASA project leaders and with specialists whose projects are supposed to be conducted within IIASA.

Software research is clearly scientific in nature and must be an integral part of the "Computers and Systems" project. The above software studies would require a team of three or four who must be in close contact with the IIASA information service and publication of papers on the systems analysis software available. These papers must be intended for all IIASA specialists. Furthermore this team must maintain contacts with national organizations for information on software.

The possibilities of receiving software can be illustrated by the following example. At the 18 May 1973 meeting about plans for IIASA computer facilities, a letter to Dr. Raiffa from Dr. Holling, the leader of the project on "Environmental Systems," was read. Dr. Holling expressed his willingness to lend his own programs for solving some of the specific environmental problems. There is no doubt that many scientists and national organizations will consider it advisable to render assistance to IIASA in its work.

It is obvious that the work on the IIASA hardware and software must be started as soon as possible so as to be completed before any activities on any other IIASA project.

It should be noted that recent scientific findings lead to computer procedures for large complex systems which make it possible:

1) to input into the computer portions of the source data on system elements and their interaction (followed by automatic composition) using standard methods of experimental data acquisition and registration;

2) to carry out automatically the change from a given formal description of each element of the system to a multi-purpose model of the piece-wise aggregate and from a given diagram of element interaction to a standard form of conjugate operators;

3) to carry out automatically the composition and decomposition of elements and subsystems of a complex system resulting from the suitability of its locating in the computer memory and its further use;

4) to change automatically from the mathematical model of the complex system to the imitation algorithm of its trajectories in a state space and the calculation of a given set of functional values;

5) to carry out automatically the structural analysis of a complex system followed by outputing the values of a given structural characteristics either by printing or in a dialog with the user; to recognize in the structural diagram of the system the typical structural configurations out of a given set of structural characteristics; and

6) to carry out the quality analysis of a complex system.

It is advisable to start with a problem-oriented package for the actual computer deployed in IIASA to handle one of the applied problems--for example, systems analysis in municipal systems, in environmental systems, or in automated control of industrial production--in order to create a working computer model and perform associated applied research.

This work can be done by a small team of three or four scientists within one and one-half to two years. Then this model can be used in solving other applied problems. Expansion of both programs for transfer to a multi-purpose model and procedures for solving other applied problems might be necessary.

Practical implementation of that package will facilitate solution and improve the accuracy and validity of recommendations received by systems analysis methods where thus far only rough mathematical models have been used which do not meet the requirements of overall utilization of information contained in the source experimental data.

To maintain hardware and software at an adequate level, the evolution of computers and their utilitzation procedure must be the object of forecasting studies.

Such forecasting has also a significance of its own, and, as noted above, the structure of many organizations and their working methods are partly a function of computer facilities and their effect on the nature of the systems analysis problems and solution methods. Therefore the implementation of many IIASA projects will require a good idea of future computers, which is obviously also important for solution of many problems not related with IIASA--at least today. This is the reason for the numerous papers forecasting the development of computing technology. These forecasts are, however, imperfect. They are rather subjective, are not based on sound scientific methods, and merely reflect the viewpoints of individual specialists or groups.

In view of the above, IIASA should set up studies in forecasting of computing technology and its effect on progress of science and technology. The ideas generated at the Kiev Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR may serve as basis for these studies. The Institute of Cybernetics offers its findings on forecasting methods and also the computer time of one of the powerful Soviet computers BESM-6.

The forecasting studies must be completed by a group of scientists including specialists on IIASA hardware and software. The research scale requires a team of about ten. Since a considerable part of their work would consist in meeting IIASA's own requirements, the team would be undermanned rather than overmanned.

Consequently the short-term research results on the project "Computers and Systems" would be:

1) Scientifically sound requirements to the IIASA hardware and its operation.

2) A well-run software service and a continuously renovated special software library at the highest possible level of perfection.

3) A forecast of computing technology development and utilization.

4) Computer procedures which allow automating the software program design intended for solving systems analysis problems.

It should be noted that the forecasting methodology proposed would be suitable after appropriate adjustment for any forecasts in the field of systems analysis and adjacent branches of science. Perfect forecasts are now widely recognized as one of the most urgent problems of today's progress.

Document J

Comments upon the IIASA Scientific Research Theme: "Investigation of Methods of Forecasting of Computer Facilities and Data Processing Systems Development"

V. M. Glushkov

The importance of the given theme for the various directions of investigations is based on the following circumstances: each of the IIASA scientific directions needs the well-founded definition of the nearest and the remote perspectives of their development for decision making in the area of planning, personnel, and organization. Obviously, the basis for choosing the scientific subjects may be realized to a considerable degree through a forecasting estimations system. It should be added that the problem itself of computer facilities and data processing systems has a global and interdisciplinary nature. The requirements for combining the efforts of the scientists of the different research areas demand the immediate development of combined forecasts, and then composing thorough coordinated short-, middle-, and long-term plans based on these forecasts.

The urgency of forecasting of computer facilities and data processing systems is all the more intense because the development of this field has an international nature and interests all highly developed countries. The involvement of the widest range of prominent scientists throughout the world in the estimation and formation of the perspectives of this field and the successful coordination of their effects will make it possible to outline the most efficient ways of developing the computer facilities and data processing systems as well as to increase the reliability of forecasts.

The accumulated systematic forecasting experience of this program may be also used for other directions of investigations which have the global nature.

The available experience of the scientific-technical forecasting abroad and in the USSR points to the presence of theoretical and methodological conditions for organizing this type of international forecasting developments. In particular, the Institute of Cybernetics of the Ukrainian Academy of Sciences has a program forecasting staff as well as a complex of algorithms for forming the data bank and for calculations on it. The programs are debugged in ALGOL for the BESM-6 computer according to these algorithms. This may be the initial stage for the forecasting of computer facilities and data processing system with the combined efforts of highly developed countries.

It is supposed that the executors of the project will take part in working out the initial concept, in the expert estimation of the technical decisions perspectives, and in the concluding interpretation of the forecasting hypotheses. It is also advisable to realize the coordination of the work on forming a data bank and developing software for calculations on it.

For carrying out the project it is necessary to organize a group of scientists concerned with forecasting questions. This group may consist of IIASA scholars and scientists of outside groups. This group must be engaged in the following:

- investigation of the forecasting methods for developing computer facilities and data processing systems
- organization of carrying out the joint expert estimation
- coordination of work on forming a data bank and developing software
- publication of forecasts.

Furthermore, the participation of the consultants and experts in the given field is required as well as that of scientists on short-term missions, carrying out the main part of the investigations in their own countries.

At the initial stage of carrying out the project it is expedient to use the software for forecasting developments available in the USSR (Institute of Cybernetics of the Ukrainian Academy of Sciences).

The following is a result of implementation of the given theme. First, the standard methods of hardware program forecasting will be worked out as applied to the objects having a global nature. Second, the forecasts on computer facilities and data processing systems which will be renewed yearly will be regularly obtained. Third, the forecasts results will be published in the "Data for 74" bulletin for the persons concerned and others.

Document K

Proposal for a Software Project: Extended Simulation Language

J. Gordesch

Simulation methods are a valuable tool in systems research. There are three main types of simulation program packages:

1) Software for special problems (as transportation problems);

2) Software for special stochastic procecesses, e.g. queuing problems (GPSS, SIMSCRIPT, SIMULA, SIMPL); and

3) Software for the simulation of continuous and discrete systems (CSMP, CSSL).

The latter type of simulation languages are of particular interest for system analysis, particularly in large socio-economic models.

The simulation languages known so far are lacking in comfortable mathematical and statistical programming facilities, and they do not provide any help in solving related artificial intelligence problems. Therefore I propose to develop an extended simulation language (or an extended version of any language as CSSL or CSMP) covering the features mentioned above.

Document L

Optimal Model Building

J. Gordesch and P.P. Sint

An algorithm is developed which builds models, optimal in a threefold way: optimal reproduction of data, guaranteed by common methods of estimation; simplicity and feasibility, ensured by automatic construction of the model with possible man-machine interaction; usefulness in explanation and projection, aimed at by using clustering techniques for variables and items.

A model is defined as a simplified mapping of reality. The reality and its picture may be either physical or mental. We confine ourselves to mental pictures only, i.e. the model will be constructed with the help of abstract concepts from pregiven data.

A model should be optimal in an at least threefold sense:

a) optimal reproduction of data;

b) simplicity and feasibility (also entailing low costs etc.)

c) usefulness in gaining additional information (explanation, projection).

To a certain degree these three requirements exclude each other. Optimal reproduction of data is achieved by the usual statistical estimation procedures, i.e. the minimization of a risk function. Certainly the feasibility of the model is promoted by automation of the process of constructing the model. The complexity of the process, however, enhances a restriction of automation and leads to a man-machine interaction. Especially the problem of explanation and similar tasks is difficult to handle automatically: the heuristics involved are too complicated for rigid algorithms and should be left to man.

An algorithm for the automatic construction of a certain class of models is developed in the following and summarized in the flowchart below (Fig. 1).

1. Data Base

The data are supposed to be in the form of values of variables (binary, multi-state, numeric) measured on well-distinguished items of a population.

2. Feature Extraction

Optional introduction of artificial variables (e.g. forming index numbers, transformation of variables as taking logarithms).

3. Structural Graph

A graph is defined over the set of all variables, where the nodes of the graph represent the variables and the edges the relations between the variables. A model is, at this stage, an enumeration of selections of elementary paths of the graph. The enumeration of even a moderate number of elementary paths is a hopeless proposition, hence a severe simplification of the graph will be necessary. This may be achieved either by the fusion of nodes (cf. 2 feature extraction, 6 clustering of variables, and 8 reduction) or by (external) removement of paths (relations).

4. External Information

Exclusion of variables and relations according to the preknowledge of the scientist. At this stage it is also possible to give the knowledge concerning the third requirement for an optimal model. Thus the variables may be divided into predictor variables (e.g. causes) and criterion variables (e.g. effects). The criterion variables represent the wanted additional information, being calculated from the predictor variables. In the sequel we distinguish between the case where the above division is provided (treated first) and where not.

5. Clustering of Items

In many cases the variables concerning subgroups may follow similar laws, and it may be worthwhile to divide the population into these subgroups. A whole battery of such clustering methods has been developed (for a survey see Jardine-Sibson and Lerman, 1971). Different models may be built for each cluster. Example: a population is divided into groups (clusters) with similar somatic attributes.

The steps 4 and 5 may also be fused resulting in a two way clustering.

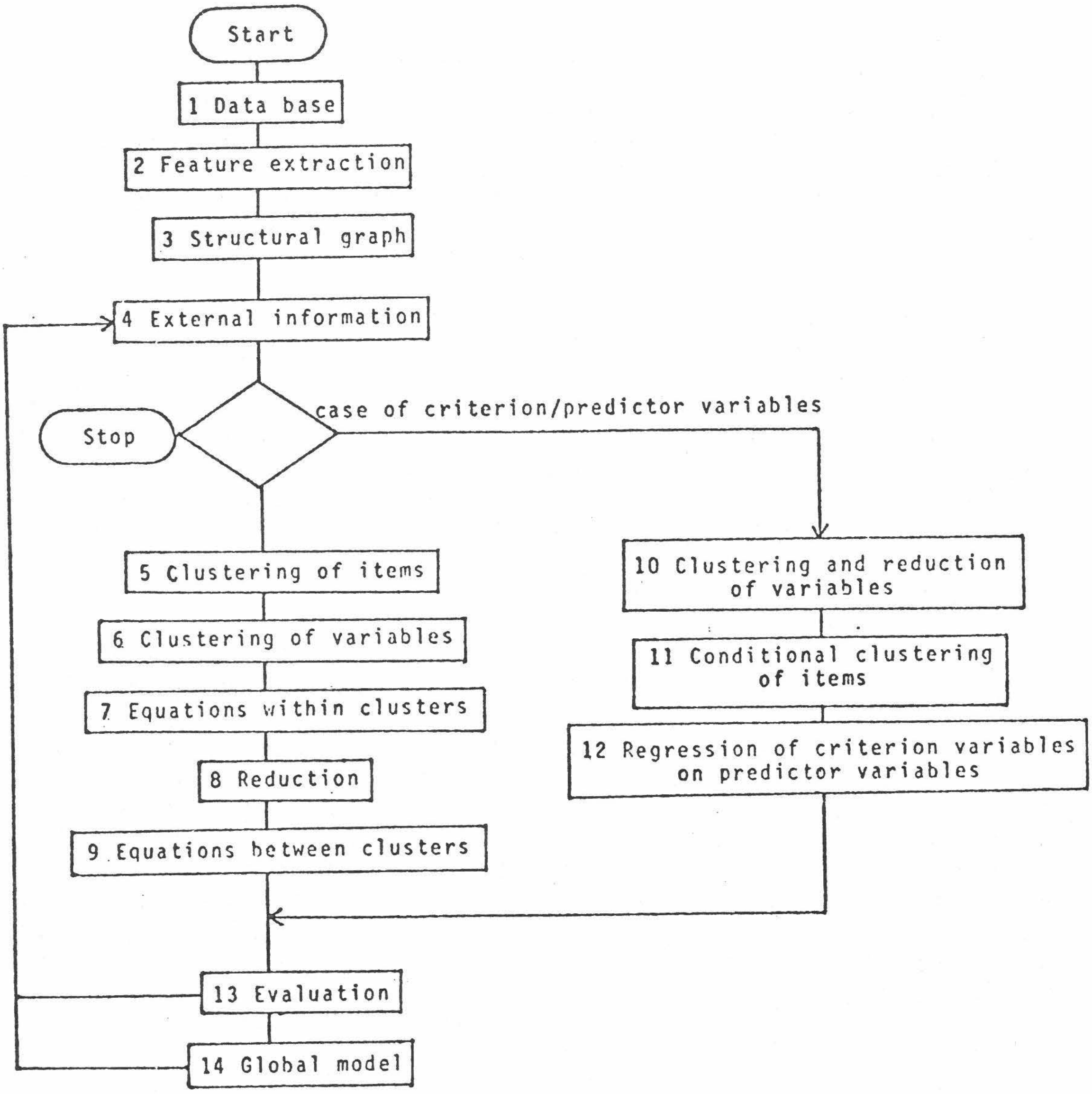

Fig. 1. Flow chart of model building algorithm

6. Clustering of Variables

Several variables may bear the same information on the items or may, at least, be approximately equivalent. This leads to the proposal to cluster the variables, and condense the variables in one cluster to one or at least fewer variables than contained in the cluster. Example: measurements on human beings may be divided into groups giving proportional results (the measurements on the left and the right hand side may even be nearly identical).

7. Equations of Variables in Clusters

Analyzing the similarities in the model leads to the construction of regression equations between variables within the cluster. Because all the variables in one cluster are equivalent, orthogonal regression is recommended (estimation of the parameters in an equation $a_o+\Sigma a_i f_i(x_i)=0$, cf. Malinvaud, 1966).

8. Reduction-Variable Selection or Factor Extraction

Now we reduce the space of variables by choosing one variable out of each cluster as representative. This may be done either arbitrarily or by some optimization process (e.g. variable nearest to the center of the cluster). An alternative method may be the concentration of all the variables in the cluster into one or more factors.

9. Equations Between Clusters

We may form an equation immediately with the aid of variables obtained in step 8. A more sophisticated approach is to start by determining a total ordering of the clusters. For this purpose we use the capacity of each selected variable to predict all the other selected variables. Now we search a path which has its first node in the first cluster, its second node in the second cluster, etc., and which is of minimal length in the sense of a "distance" function between the variables (e.g. $1-|r|$, r correlation coefficient, or some "distance" derived from measures of association). These variables are included in a regression equation the coefficients of which are estimated by the method of orthogonal regression (cf. Malinvaud, 1966). Several algorithms exist for finding a path of minimal length in a directed labelled graph (see e.g. Albrecht, 1969; the method of dynamic programming: Bellmann, 1957). It is, however, necessary to find not merely the best policy but also the second best, the third best, etc., the k-th best:

$$a_o^{(j)}+\sum_{i=1}^{n} a_i^{(j)} f_i(x_i) = 0,$$

$j=1,2,\ldots,k$ number of subpolicy (equation),
$i=1,2,\ldots,n$ number of variable

$a_i^{(j)}\neq 0$ for one and only one element x_i in each cluster.

For when we determine an exact solution ($j=1$) to the mathematical problem of optimization, we may have only an approximate solution of the real problem. If a mathematically optimal solution is unsatisfactory from the viewpoint of reality, we can either find a suboptimal solution ($j=2,3,\ldots,k$) in hopes that it will be better from the viewpoint of reality, or reformulate the mathematical problem (see 13 and 4).

10. Clustering and Reduction

Separate clustering of predictor and criterion variables and replacement of variables in each cluster by a selected variable or a factor (optional).

11. Conditional Clustering of Items

While traditional clustering methods use all variables indiscriminately in the criterion of assessing the quality of a classification, conditional clustering uses only the criterion variables. On the other hand, the classes may be found with the help of the predictor variables alone. Example: healthy people are classified into classes for which similar medical diagnostic methods in the case of illness promise good results. Several conditional cluster methods result in classes of items for which the relationships (cf. 12) of predictor and criterion variables are similar. For a more detailed description of the method see the Appendix, and Sint, 1971.

12. Regression of Criterion Variables on Predictor Variables

At this stage the parameters of the system of equations

$$y_i = \sum_j a_{ij} x_j \quad ,$$

where i = number of criterion variable, and
j = number of predictor variable,

are estimated by a method described by Golub, 1965.

13. Evaluation

This step yields the evaluation according to our three requirements of optimality, particularly the optimal reproduction of data, and prepares the basis for external evaluation.

14. Global Model

Finally the various submodels constructed are combined to one global model, which may still be reformulated (see 4).

The performance of the model depends essentially on the quality of the clustering process. A system of programs is in preparation; parts of it, a subroutine control system (SCS) developed by M. Winterleitner, and programs for various algorithms, are already working.

For the special problem of causal models see Gordesch, 1972.

Appendix: Conditional Clustering

Traditional clustering methods try to subdivide the space of items into regions of "similar" elements. The location of an item is given by a vector of the values of its attributes.

Assuming k attributes x_i we describe an item e by a vector

$$e = (x_1, x_2, \ldots, x_k) \quad ,$$

and a non-hierarchical clustering method is a mapping

$$C: e \rightarrow n, \ n \in N,$$

where N is a nominal scale, conveniently a finite set of integers. In addition, the variables are used as criterion to decide on the quality of the clustering achieved. The method of Edwards and Cavalli-Sforza (1965) for example, searches for clusters for which the sum of variances within the clusters will be minimized.

In conditional clustering we assume that there are two different types of variables such that an element is described by a vector of k predictor variables and l criterion variables,

$$e = (x_1, x_2, \ldots, x_k; y_1, y_2, \ldots, y_l) = (x, y) \quad .$$

While the process of assigning an element to a cluster is done by the predictor variables, i.e.

$$CC: x \rightarrow n, \ n \in N,$$

the quality of this clustering is evaluated by the criterion variables. The clustering of the elements by the predictor variables is subject to the condition that the clusters should be homogeneous in the criterion variables. Classical cluster analysis searches for densely populated regions in the given attribute space, whereas conditional cluster analysis aims at the prediction of the values of the criterion variables, which may be achieved by searching for dense regions in the criterion space and studying the corresponding regions in the predictor space (see Fig.2). It may even happen that regions separated in the predictor space correspond to similar elements in the criterion space.

In traditional cluster analysis, the criterion used (e.g. minimum within cluster variance) determines the method of partitioning the underlying space. The method of subdividing the predictor space, however, is not necessarily related to the criterion for evaluating the resulting clustering. Each method of pattern recognition may be used in this process. One method of determining the clusters--a rather restricted one--searches for dense regions in the predictor space which correspond to dense regions in the criterion space. These methods find clusters for which the relations between predictor variables and criterion variables are similar. Hence they are especially useful for our algorithm of model construction. Regions not connected in the predictor space will be separated in this case, one of the features we could not take account for in the above model because of the necessary simplicity and feasibility.

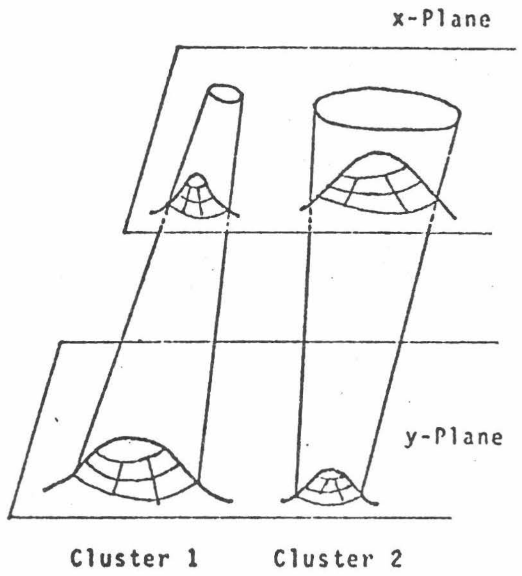

Fig. 2. Conditional Clustering

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Document M

Addendum to Some Proposed Projects

Automatic Model Building

J. Gordesch and P.P. Sint

Model building is a difficult and time consuming task. Some automation may be of great help, as one can see from stepwise regression algorithms. The means available now are rather restricted, and a lot of further development will be necessary. For some special modelling methods see the paper:

J. Gordesch and P.P. Sint, Optimal Model Building. Proc. 3rd IFAC Symposium on Systems Identification and Parameter Estimation. The Hague/Delft, 1973.

Automatic model building may also be seen as a special part of the following proposals for projects of IIASA or be, at least, related to papers presented at the ongoing conference:

"Computer and Systems," "Artificial Intelligence," "Automation of Design," "Investigation of Methods of Forecasting of Computer Facilities, etc.," "Some Notes on the Research Planning of Computer Science, etc." (Nishino).

Document N

Proposal for a Language Project: Problem Oriented Languages

N.J. Lehmann

There are at least three main aspects that should be considered when dealing with linguistic resources within the framework of applied system analysis:

1) Utilization of problem oriented languages for computerized system analysis with various areas.

2) Analysis and examination of the quality of languages and organizational systems (including compiler generating facilities) as precondition for their official application.

3) Language as a fundamental of communication with "intelligent systems" (dialogue systems and artificial intelligence problems).

To accomplish this and to select adequate remedies for further work on the various problems to be made by the Institute, a working group of 2-3 scientists should be charged with this work. The work should be done in close cooperation with the Software Group and the Forecasting Project and in liaison with other institutes. Based on the obtained results and generalizations, the Working Group would then be able to further promote the development of programming language systems directly.

Document O

Random Comments

C. Newton

1. Bibliographic Problems

Consider a conference soon of several days' duration. People to include: postal and airline authorities, prospective librarian affiliates, MEDLARS representative, telephone expert (to get prices on facsimile equipment). By solving IIASA's bibliographic problem thoughtfully, a step may have been taken toward wider bibliographic support for the world's scientists.

Professor Dobrev indicated that he gets 80% text reduction by automatic abstracting techniques. This may suffice for short articles. For longer ones, IIASA might lead the way in encouraging major journals to require abstracting and classification of all articles by their authors. Classification pointers and abstracts probably should be stored locally (in each country), with central retrieval from IIASA or a UN computer. Is automatic, crude translation of abstracts feasible?

2. Systems Study for Internationally-Subsidized Communications

Would a systems study of the essential communications needs of WHO, WMO, IIASA, and other important international organizations that serve the public reveal that there are cost-effective alternatives to the present tangle of private and governmental communications systems?--e.g. Could the anticipated load be large enough to be handled better on special international satellites?

3. The Proposed Project on Forecasting Computer Technology

The idea of undertaking a project in forecasting is superb, as is that of exploring how expert opinion can be effectively utilized. But the proposed topic to be addressed--computer technology--does not seem promising. Commercial and perhaps even some government developers may not want to reveal their latest work. Recent breakthroughs (e.g. IC's, virtual memory) have been different in kind rather than amount--so that we might expect that important new elements might be added to the state vector within the forecasting period. Finally, if it is noted that some countries have been more reluctant to reveal new computer technological work than have others, strained relationships might develop early in IIASA's program--which would be unfortunate. Perhaps the methodologies could be developed first on a more tractable problem, leaving open the hope that the computer technology problem might be addressed later on. How about the predicted world food crisis?

4. Terminal Selection

Since a discussion on the choice of terminals didn't open up, let me extend yesterday's remarks.

Let us survey now the computers in various participating countries that are likely to be accessed by IIASA. Simple questionaires probably would suffice for openers, granting that we are not going to reach all possible computer centers. Consider it a sampling. Find out what terminals they support now, especially those that would support teleprocessing, and the interface specifications. Also, do they see their operating systems and some of their compilers as being compatible with or closely resembling those on other major machines? (e.g. there is word that one of the Soviet Union's large machines is being designed to look pretty much like an IBM OS machine. I also have heard that Siemans is considering a similar compatibility.) Do these machines support remote interactive graphics? One might wish to make initial applied software investments more for machines that can exchange software, provided the applications targets are equally worthy.

Choose one or more types of inexpensive terminals, on the basis of the above, to start with. Except for investigators who work primarily in computer science, I suspect that it is not necessary to place a terminal in each investigator's office, although it might be nice.

Next, and as soon as possible, get a good, sophisticated graphics terminal. You may want to add more, cheaper, and otherwise more attractive graphics terminals later, but now give considerable weight to the terminal's associated software and proven ability to operate remotely over noisy, conventional telephone lines. Among things to consider are:

a) Is new applications software development likely to be rapid on this system? Convenient FORTRAN or PL/1 graphics languages that hand the programmer a conventional I/O capability and a good mix of tools for handling interactive interrupts greatly facilitate development of new applied software--with respect both to new coding and to use of a wealth of existing subroutines or of entire, well-tested programs that can be used as subroutines. For example, if one wants an interactive program for fitting non-linear functions to data, a FORTRAN-based language like GRAF enables the program developer to call something like BMDX85 (the BMD-series FORTRAN stepwise non-linear regression program, which has been improved to handle ill-conditioned situations over many years of use) for computations, concentrating his new programming efforts on convenient function-specification, data input, and bounds-setting conversational routines, as well as versatile graphical outputs. While a good interactive graphics program's architecture usually should be quite different from that of a batch counterpart, there is no reason not to use the latter's subroutines.

The need for rapid program development is fairly universal, since one wishes to lower a user's reluctance to engage in a graphics approach and to write disposable programs that meet his immediate needs, just as he would in conventional FORTRAN. The need at IIASA is even greater, since one wishes to help the investigator make the most of a brief stay. The language should be simple enough so that the user himself can make minor program revisions at night and on weekends, without having to await service from IIASA's programming staff.

Because things like execution efficiency and various costs are more obvious and easier to measure, we tend to unduly weight them in our decision making. IIASA's most precious resource is its scientific manpower. Unless it is clear that hard financial constraints are being encountered, the highest value should be placed on computer-support effectiveness and program development efficiency as seen by the user, rather than upon economy of terminal hardware (when one is talking at most of costs no greater than $25,000) or the utmost in efficient computer utilization.

b) Can the terminal access its host computer over ordinary voice-grade telephone lines? IIASA may hope someday for special leased lines or other forms of broad bandwidth communications support to remote graphics terminals, but it is essential to inaugurate some graphics support as soon as possible. Alternatively, rapid-response terminals are possible when locally supported by their host processor. However, graphics is most needed when complex retrievals and modelling problems are encountered, so the local processor had better be rather adequate---i.e. not just a mini (and look at what those "minis" cost!!). IIASA is wise to defer a major processor acquisition until the mix of problems in which it will engage, and alternative remote hardware supports for same, are better known. Thus, at least its early graphics developments should presuppose the terminal's access to a major remote computer by way of voice-grade lines.

This implies a need for a display that is selectively erasable. Often a complex graphics display is maintained while small messages prompting or receiving input from the user are varied. Response time becomes disturbingly long, even with a 2400-baud modern, if the entire display must be retransmitted every time a portion of it is altered. It suffices for now to note that this capability may be attained in a number of ways; just be sure it is there.

Line noise can seriously impair response times and crunch fragile software systems. You can bet that there will be a fair amount of it. Thus, intelligent terminals are preferable; their computers can be used to cope with line noise. Also, they can unpack condensed instruction strings, temporarily store transmitted display variables that are likely to be reused, reconstruct curves piecewise from transmitted parameters, etc.

c) Can available software be utilized? Here is where your survey of machines that IIASA might use, as well as some idea of who the early graphics users will be, becomes important. A graphics software system that meets most of the foregoing criteria is available for IBM 360/370 systems running under OS. If the news from the Soviet Union and from Siemens is right, it may adapt to relatively wide use. The CBIH (Chemical-Biological Information Handling) project in the Biotechnology Branch of NIH's Division of Research Resources now has a Request for Proposals out for intelligent graphics terminals that will access their PDP-10 over voice-grade lines. The simple storage-scope terminals with which they began have proven to be a false economy and will be retired. For instance, the system has been extremely fragile to line noise. BB and N will develop the software. However, this means a delay.

I would suggest that this preliminary terminal be regarded as a temporary expedient, but a good one. Insofar as is possible, use available software--especially if applications programs you might also want are available on it as well. Remote graphics software development looks disarmingly simple in prospect. Unless you can hire a programmer who already has considerable experience in this type of systems software, a decision to start from scratch could prove to be very costly and handicapping to your primary mission.

d) Prefer a terminal that has software character generation. Admittedly, this is minor relative to the preceeding considerations. However, even though IIASA has an official language, its international orientation suggests that, whenever possible, scientists should be able to work in their native languages. Changes in character sets are relatively simple with software character generation, and special symbols, such as integral signs or map symbols, can be stored as well.

e) Another minor consideration is a compiler for the intelligent terminal's associated minicomputer. The latter can do a lot of valuable work in the stand-alone mode (e.g. some simple text-editing, or some aspects of problem specification), especially if it has an associated disk. Its associated large host computer can be used to generate object code for it. When you're "shopping," ask if the terminals you are offered have such associated software for associated host computers.

A general comment on applications programming: I think that people are struck most by an interactive graphics terminal's helpful displays of output and facility for guiding and truncating computations (a real economy in large-scale modelling). I have found, however, that aids to model specification are among the terminal's most important contributions. The drudgery of specifying a realistically complex model can discourage its use. Furthermore, considering the great expense of eventually running the model, all possible checks for errors, range of applicability of functions, correctness of form of functions, consistency, etc., are indicated. Considerable applied programming skill should be developed in this area.

5. Computer-aided Design

Computer-aided design related to computers is an interest at UCLA's Department of Computer Science. The best person to contact is Dr. Gerald Estrin. I have encountered dissertations in both layout of logical elements and utilization of chips (Richard Chesrow). A recent dissertation by Harry Taxin and one in preparation by Ferrand deal with different general aspects of graphics support to development of design diagrams.

6. Problem-oriented Languages

I endorse the recommendation of Dr. Lehmann and others that problem-oriented languages, and especially tools to facilitate their construction for different types of applications, be appropriate targets for IIASA-sponsored research in computer science. I would enlarge this slightly by noting that, in flexibility and breadth of the domain of computations that can be specified, some interactive programs (e.g. some graphics programs) can resemble languages considerably, except for obvious "linguistic" interfaces to the user. What they lack in elegance, efficiency, or greater generality, they may partially compensate for by providing the application-oriented user a tool that is inherently more self-explanatory, that is easier for him to learn to use (e.g. he doesn't have to remember mnemonics or grammars) than most conventional languages. It might be profitable for people with linguistic and user-oriented interactive-system backgrounds to collaborate on an important, well-defined project, using it as a vehicle for comparing and perhaps combining these approaches.

I now can see that applied systems analysis has much in common with a number of areas of biomedical research: Problems tend to be complex and heuristic supports to the user important. It is necessary to involve the applications experts as immediately as possible in model and data-base exploration, to minimize the necessity for dependence on computer-related or routine mathematical professionals in their on-going work.

It also often is important to facilitate simultaneous investigation of a problem by professionals with quite different backgrounds. I suspect that other research areas such as economics are the same. It therefore would be interesting to investigate not only general modelling or file/retrieval languages, but also to learn what languages and interactive systems are supporting research in intrinsically complex, multidisciplinary, and non-computer-science-oriented disciplines such as the above.

Here are a few concrete proposals:

a) Survey what is available in languages serving modelling and/or fill construction and retrieval. Gather an international team of people, like Jean Sommet, whose knowledge of languages is broad and who are likely to write a critical review that is understandable to computer-knowledgeable applications scientists.

b) Form another international group of people in various applications areas who have sought other means, such as interactive approaches, to provide investigators who are not computer-knowledgeable effective access to exploration of complex models and data bases in specific applications. (It is important to compare what results when one seeks to optimize support for scientists in one specific area of investigation with what results when generalization is a more important objective.)

Note: The foregoing undertakings, if accomplished at a high level of quality, are rather ambitious and may require a fairly high travel budget. Perhaps the focus can be narrowed.

c) Next, formulate a problem area, one that IIASA wishes to pursue on the basis of other considerations. Using what has been found in (a) and (b), form a team of people with different backgrounds in interactive and linguistic techniques. This team will use the problem area as their laboratory for basic research on combined techniques to aid applied investigators. Pressures should be removed for them to provide immediate service--e.g. by assigning adequate standard programmers to the applied investigators. If an area is chosen to which IIASA has a long-term commitment, it may be possible to form some impressions of one relative effectiveness of low-level ad hoc programming and more sophisticated supports at different stages of an investigation.

7. A Project for AI: "Semi-Automated Model Exploration" (SAME)

This is related to the foregoing. For example, given that a model specified by some language (e.g. FORTRAN) meets certain criteria (e.g. has less than a certain number of conditional branch points, less than a certain level of nested recursive cycles, etc.), various relationships between variables, parameters, and boundary values can be deduced. For simple models, these relationships might be effectively stated immediately. However, for complex models, one suspects that they are most effectively expressed when the user has narrowed the domain by specifying certain parameters, branches, etc. Even in investigations of single models, exploration would be more efficient if the user were reminded that certain variables are unrelated to others, that raising a given parameter's absolute value will monotonically decrease a variable's value at all points of a given domain, etc. In comparative investigation of two or more alternate models, an extension of these automated aids to model exploration might be able to suggest the most effective variables to observe, most effective choice of parameters within allowable limits, etc., to distinguish between models. Later--far down the road--one would like to see this support extended to the interfacing of models to data--e.g. given a set of data and models to be compared, where are additional data most badly needed?

It is possible that such work already has been done in AI. If so, I should like very much to learn of it.

Document P

Some Notes on the Research Planning of Computer Science and Artificial Intelligence

Hiroji Nishino

In examining the research themes at the IIASA concerning computer science and artificial intelligence, we think it necessary to elucidate several basic concepts.

The description of an approach to the Applied System Analysis which appeared on the paper of "An Initial Research Strategy," prepared by Dr. H. Raiffa, is quite instructive.

1. It is necessary to recognize, along with the IIASA's objectives, the importance and general nature of the problems from an international viewpoint.

At present, the advanced industrial countries are confronting a variety of common and trying problems concerning resources, environment and society. For instance, most countries involved keenly recognize that the time for an international control of natural resources is long overdue.

Under these circumstances it is obvious that in solving these problems, the preparation and the management of the huge data base by using computer systems will play an important role.

2. There must be a united international effort if these problems are to be solved.

The mere recognition of the importance and common nature of the problems, as mentioned above, is not sufficient. For instance, although, in reality, the different policies and economies of each nation become predominant factors in the resources problem, the emphasis should be placed on how to set up a technological basis for the effective utilization of finite natural resources.

If we examine a problem like world dynamics, we will inevitably be led to the recognition that, so long as nations are allowed to freely pursue their own policies, clever world-wide management can never be realized. Hence the need for finding basic methods for analyzing and managing the problems.

In order to establish a common method under these conditions, it will be necessary to have computer science and technology concerning large-scale information and control systems play a leading role. These problems will cover a wide range, from the uniformity of the approximations in global and local models, the decomposition method of large scale simulations, the sensitivity of a variable to the total system, as well as the system's stability, to the common handling of data and utilization of common language and software packages.

3. There must be practical international cooperation.

However much the importance and necessity of solving the problem are conceptually recognized, if international cooperation is not realized, this recognition is meaningless. Thus, there must be strong interdependence among nations concerning the problems, and necessary information must be easily exchanged.

For instance, with regard to global meteorological information, the mutual exchange of data through nations' observation networks will be vital. Moreover, by using methods like meteorological satellite observation and the automatic analysis of data obtained, the solving of these problems can be speeded up.

In addition, there is a great possibility that, on the basis of worldwide communication system, a computer network will play an important role in on-line weather forecasting. Here, concrete computing facilities are important.

4. As its object of study the IIASA should choose such themes where study is still in its infancy, and ideas which have not been adopted as an industrial technology anywhere in the world.

We feel that themes like those which the computer industry is now competitively developing should be excluded from the IIASA's studies. Instead, in pursuit of the construction of a substantial welfare society, emphasis should be shifted to the research and development of the improvement of man-machine communication, understanding of human intelligence and so on, by using highly sophisticated information processing techniques.

5. Finally, concerning information processing, it will be necessary to maintain favorable liaison between such international organizations as IFIP, IFAC, etc.

In view of these basic ideas, some examples of study themes which are thought to suit the IIASA's objectives are listed below. In order to solve the mounting complex problems the IIASA should present effective technological measures, independently of nations' policies and economies.

1) Theoretical and empirical analysis of a large-scale control system, aimed, in particular, at expanding the range of application of theories and methods to social or eco systems.

2) A variety of processes for global-wide simulation.

3) Technological problems concerning the preparation of a huge data base and its management.

4) A worldwide computer network. In particular, those which are not commercially developed, but managed on a non-commercial basis.

5) Performance evaluation of a large-scale information system, and techniques to operate it.

6) Machine translation on a multi-lingual basis, especially translation which has a practical objective.

7) Computer-aided instruction conforming with the IIASA's objective.

8) Improvement of man-machine communication.

Document Q

Comments on Submitted Proposals and Discussions

Hiroji Nishino

1. Computing Facilities

    1.1 Main Computer
        *Prof. McCarthy's remarks

    1.2 Computer Network
        *future problem

    1.3 Remote Job Entry (R.J.E.)
        *no comment

    1.4 Time-Sharing System (T.S.S.)
        a) commercial T.S.S.
        b) in-house T.S.S.
        *recommendable

    1.5 Dedicated Mini-Computer System
        *application-oriented

2. Software for Supporting Whole Set of Projects

    2.1 Data Base Preparation and Management
        1) data base preparation system (D.B.P.S.)
        2) data base management system (D.B.M.S.)
        3) man-machine communication system (M.M.C.S.)
        *should be developed, referred to Fig. 1

    2.2 System Description (Analysis, Design) Language and System Simulation Language for Comples and Large-Scale Systems
        1) modelling ------- analysis
        2) implementation on a computer ------- design
        3) simulation
        4) reporting
        5) evaluation and decision making
        *should be developed

    2.3 Other Utilities
        *should be taken in consideration

3. Voluntary Research Themes in "Computer Systems" Field

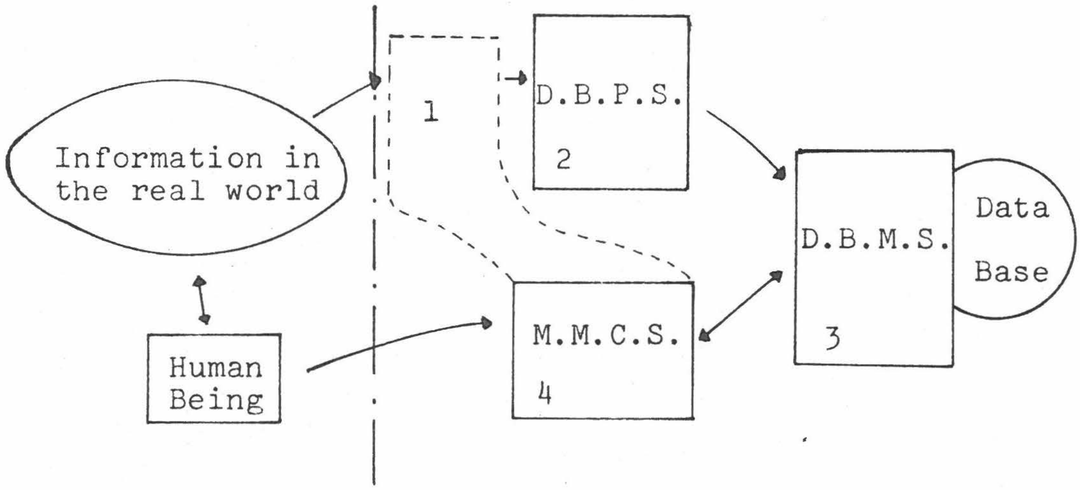
3.1 Forecasting of computer technology development and utilization
*doubtful

3.2 Development of a controller model
*not agreeable

3.3 General studies of programming languages
*should be concentrated in a specific subject

3.4 Automatic program writing
*ibid

Figure 1. Data Base Preparation and Management



1)
- automatic indexing, abstracting (natural language understanding)
- pattern recognition

2) D.B.P.S.
- text editing
- terminal management
- computer graphics

3) D.B.M.S.
- host language system or self-contained system

4) M.M.C.S.
- conventional IR, more sophisticated IR
- natural language understanding
- Q-A system
- computer graphics
- speech response system

Document R

Notes About Computer Applications in Information Transfer

John Page

Present Status

Nearly every commercial application of computers involves a degree of information transfer. For example, in the banking systems, the transfer of information between computer terminals in the branch offices and the central computer facilitates the continued updating of a major bank's trading position. Except so far as all such commercial applications involve communications networks--which could conceivably be shared by other types of users--the investigation of such systems does not seem to be a prime target for Systems Analysis. Two other types of information transfer systems may, however, be of greater interest: scientific and technical information systems (STI), and management information systems (MIS), in the widest sense of the term.

In both cases there are policy problems, involving an assessment of the value of such systems to the user, contrasted with the necessary investment in development and operating costs. These problems may also be influenced strongly by advances in computer and communications technology. They may therefore be fruitful areas of investigation by Systems Analysis techniques.

STI Systems

There are many current examples of computerized STI systems, designed to meet the needs of scientists and engineers in particular fields for bibliographic information enabling them to locate reports and articles relevant to their research and development programs. The rationale of the development of all such STI systems has been the exponential growth in scientific and technological literature. But there seem to be a few valid studies of the comparative value of such systems to the actual user, as compared with other methods of transfer of information which, as they form part of what could be termed the internal sociology of science and technology, exist side by side with computerized STI systems. It is, indeed, very difficult to conceive of simple value measurements in this area. But such indices are required, not only to facilitate the strategic decisions (i.e. the priority to be accorded to further computerization), but also to form the basis for tactical decisions, i.e. what are the users needs in a particular field and how best to meet them from a technological point of view.

STI Networks--Technico-Economic Aspects

Two new features have appeared in recent years in STI systems. The first is the development of interactive, real-time systems, permitting a dialogue between users remote from the computer and data banks consisting of possibly around one million references to report and journal articles.

The second new feature--associated with the first--is the networking of STI information through tele-communication channels to serve as large a user population as possible from the same central computer facility. The latter may in some ways be regarded as an economic consequence of the relatively large investment needed to develop and operate interactive, dialogue systems. A further heavy cost is necessary to collect, process, and computerize the many items of scientific and other information necessary to construct a comprehensive data base for a particular scientific discipline or for a project oriented data base. To achieve economies of scale it may in future be necessary both to rationalize the collection of information, and to combine several major data bases in one computer installation. (At present, one can expect about a thirty per cent overlap in coverage between any two data bases in the physical and engineering sciences.)

In present day networks, the relationship of communication costs to storage costs (i.e. the dedicated mass storage on the computer reserved for STI files), and its trends for the future would repay investigation, since this kind of relationship will be an underlying factor in future network development. If the present trend toward reduction of storage costs is maintained, the limiting factor is likely to be the high level of communication costs for major network expansions. A study might show that the real limitation is communications technology and economics rather than computer economics. Again on the tactical level, investigations of the technological possibilities for direct input by such means as optical scanners might be a value in assessing how far significant increases in cost effectiveness of STI systems might be obtained in the future.

MIS System

Present day MIS systems are largely designed to provide the management of large enterprises with day-to-day or week-to-week financial information. Doubt has been raised whether the output of these systems really improves the decision making process. A general subject for Systems Analysis here might be, as with STI systems, study of what the user really requires and of the cost effectiveness of meeting these requirements either wholly or partially. There are, however, other areas in which a true management information system, involving more than purely financial information, might be of great value, e.g. in central, regional, or municipal government.

Future Possibilities--Comprehensive Information Systems

There has been much activity in the last year or so in projection of information needs and technologies, into the future, e.g. by Delphi type studies. Some of these studies have led to the concept of the need for comprehensive information systems, in which a user sitting at his terminal, could have access to successive layers of information but on a very broad basis, in basing both STI and the ideal MIS type of data. At the top, or most general, level, the information files would be so structured as to aid decision making in general policy areas, including research and development. At the lower, or most detailed level, the data banks would be essentially of the same character as present day STI data banks; The whole complex of files would be linked in a manner analogous to present interactive computer retrieval techniques.

However, these studies tend to be fragmented, and unrelated, and to some extent all of them suffer from the lack of a systems approach. There has been difficulty in defining technological goals and possibilities in terms of an objective appraisal of user needs and overall economics. Systems Analysis might be a valuable tool in bringing coherence into this area of forecasting.

Document S

Proposal for a IIASA Project: Study of the International System of Information Exchange and Retrieval

P.P. Sint

Many national and international institutes collect information--whether data or literature--concerning various fields. They also develop information retrieval systems to serve their users. We propose for IIASA to study this system as a whole.

One would have to study who collects what, and how information is exchanged between the different information centres. The special aim would be to make proposals:

a) how to improve the exchange of data,

b) how to make information retrieval facilities in one place accesible in other regions, and

c) how modern technology may be used to introduce cross references in each information retrieval centre to others.

It would not be the task of IIASA to introduce new new systems itself. But IIASA could:

1) give incentive to other national or international organizations (e.g. UN, ITU) to do this job,

2) give some initial guidance how to do it, and

3) bring together interested centres.

This would be of special use for smaller information centres which may get hold of larger facilities.

Document T

Analysis of Corresponding Patterns

Proposal for a Project of IIASA (Artificial Intelligence)

P.P. Sint

Pattern recognition in its supervised form tries to discriminate patterns which are well known. The algorithms achieve this either by an inbuilt definition of the different patterns or by a training mechanism, where a sample of patterns for which the classes are known, are fed into the pattern recognition device to calibrate it.

In non-supervised pattern recognition (cluster analysis) on the other hand, an unclassified amount of elements is divided into subclasses such that elements in the same class are most similar while those in different classes are rather different. The classes found are homogenous but differ from each other.

A very frequent situation in analysing an (at first sight unstructured) batch of data is that there are data from different realms, e.g. auditory and visual perception, somatic and psychic data concerning a person, technological and social information concerning a society. In these cases it is often wanted to identify patterns in one realm which correspond to patterns in the other realm. Or, if the data of one domain are more easily (more cheaply) available, one may want to classify the individuals by help of these data conditional to the request of achieving classes giving optimal information concerning the other domain. This is an asymmetrical question opposed to the symmetrical above. The two domains may be the same data at different times. Later on one may envisage studying more than two domains at the same time.

Algorithms to achieve this have to start either from natural clusters in both domains (spaces) or from a preliminary solution of the problem given by the special field of application and human intuition. Especially one would have to select the appropriate level of condensation in each domain in an interactive way. The algorithms would have to improve first estimates of corresponding classes without giving too much weight to the starting values.

Only to give an idea how such algorithms may work are two references: Morgan, J.N. and J.A. Sonquist, 1963. Problems in the Analysis of Survey Data, J. Am. Statist. Assn. 58, 415-434; Sint, P. Conditional Clustering, Proc. of the 37 Session of the Int. Stat. Inst. (ISI), Vienna, 1973.

Effort will be needed in the field of pattern recognition, in heuristic pattern solving, and in learning systems. Probably results will be derived more easily using the discriminatory approach to pattern recognition but syntactic grammatical approaches to the problem may be useful. As heuristics are necessary and the human brain is still performing best in this field, in many intermediate steps possibilities of man-machine interaction should be provided.

A program in this direction should combine different forms of condensing data, different forms of intersecting the given domains, different heuristic procedures and ample opportunity for human interaction in the whole process to fit many possible applications. There already exist many methods which tackle parts of this problem but there is no system which brings them together in a uniform way.

Just this combination of quite different approaches may need efforts of people with different backgrounds brought together by IIASA.

Document U

System Approach to Computer Development

J. Vlcek

I. Philosophy of the Problem

Our contribution is based on the assumption that approaches to development of computers can be divided into the following stages.

During the first stage (the so-called first generation and the beginning of the second generation of computers) to a decisive degree the structure and architecture, functions, programming, and use of computers were influenced by technical means available to a designer. Electronic elements and their combinations in more complex circuits or chains that a design engineer was able to produce from these elements predetermined other vital categories of computing technology.

During the second stage (the so-called second and third generations of computers) it was the programming technique; more exactly the technique of operational systems and/or compilers, that became a decisive factor. Figuratively speaking, designers and engineers produce computers in accordance with the requirements of programmers, although these requirements now do not form a comprehensive and closed system as was the case of circuit logic during the first stage. There, the result is that improvised requirements of programming techniques are met by designers by means of advancing adaptation. In comparison with the first stage, this is a negative phenomenon caused most likely by the complexity of systems related to program algorithms of procedures and techniques which are higher than they were before in the framework of a relatively closed system of circuit logic. Consequences of this phenomenon can be found in a comparatively low effectiveness of present computing systems, the effectiveness being measured by the ration of the service time and the net active time of computing systems.

During the third stage (the end of the so-called third generation and probably the fourth generation of computers) decisive criteria governing the construction of computers will fall within the scope of requirements connected with their application and use. These requirements, however, should not be confined to relatively simple demands calling for high speed and large capacity of computer memories. These requirements will come to the fore in the course of extensive "organized inclusion" of a computer in an external process, i.e. the process of application and use. This problem can be characterized as a typical system problem within the framework of which a computer constitutes a subsystem of a higher system. At the same time, however, it is not a subsystem (in the sense of being a part of a system) that could be mechanically singled out and separated; but in this regard the computer is rather an aspect or a feature of the system. A significant pattern of realization will lie in computer networks which--from the standpoint of such systems application--will also raise the qualitative level of the problem. We assume that these questions could develop into a large systems problem the magnitude of which is determined, on one hand, by methodological problems (instruments of project and analysis of a computer system possessing the above- mentioned qualities) and, on the other hand, by its scope. In the framework of this problem, questions of the computer development proper as well as questions of external processes, especially those related to the process of management are integrated in one large entity. In turn, all of these processes also represent complex systems and, at the same time with "classical" problems of technological construction of computers and their programming, having originated during the first two stages, will still be in force because the next generation of computers will not solve them automatically.

The problem bears a specific difficulty, namely, a relatively rather complicated and less systematic set of programming requirements. Negative consequences of this fact were felt already during the second stage. They will be even more expressed in case of requirements pertaining to the process of application as an external process in which the computer will be supposed to be included systematically. It should be noted, moreover, that the requirements of application and use, although still more complex and still less systematic, are of primary importance. This fact might also call for formulating a task to be taken up by IIASA.

Finally, there is still another reason for formulating such a task. In particular, within the framework of the concept of approach to computer development as indicated above, subjective approaches of individual firms put forward by them as objective development trends in proportion to their individual shares in the world market of computers are becoming a factor of retardation. IIASA as an independent agent in the market could thus contribute to the rationalization of development of computers in the world. To a certain degree approaches of large American universities may serve as a spontaneous illustration of this function.

II. Orientation and Contents of Partial Tasks

Despite difficulties presented by this problem, at least the following basic orientation of approaches can be indicated at present.

1) Formulation of partial tasks constituting the problem (questions related to interface between the external process and computer system as well as its application; throughput capacity of the computing system in relation to external process; adaptability and limits of alternative behaviour of computer systems; conduct of the computer system in cooperation with an external process not fully informed; particular problems of system languages such as description of external as well as computing processes by means of such a through language), and the development of methodology pertaining to the solution of these system tasks;

2) Development of simulation techniques for such heterogeneous supersystems in view of the fact that costs of direct experimentations are too high and that any experimentation is practically impossible;

3) Development of such methods that will enable the translation and adaptation of results from problems in 1) and 2) for individual concrete conditions; and

4) Experimental testing of concrete applications and diffusion of knowledge on international scale.

Results of research and development activities could not only constitute a source for theoretical publications, but in the form of expert studies they could also serve manufacturers and consumers of computers.

Document V

Remarks on the Topics of Research Planning Conference on Computer Systems

J. Vlcek

A. Computer Systems

1. I think IIASA will never have the sufficient manpower to solve directly the problems as destinations of near-specialised languages, to construct the translators for them, and to bring them into practical life. I have in mind the examples of the activities of such organizations as IFIB, CODAJYL, IJO, producers of computers. There is also the fact that at this time there exist more than 250 programming languages in the world oriented at everybody's service.

Proposal: Rather, I think IIASA should: 1) evaluate the existing languages with respect to systems analysis algorithms, 2) make suggestions, and 3) perhaps publish these qualified suggestions and evaluations.

2. For the same reasons I think IIASA will probably not be able to develop and realise the specialised user-operating systems oriented to a general field of systems analysis methods and procedures.

Proposal: The same as above.

3. As to the suggestion that IIASA should orient its activity as a clearing house or library of programs and solutions, I fear that such activity would be very seriously constrained by organizational, financial, and juridicial problems.

Proposal: It seems better to pool the scientists and professional people in the form of integrated and problem-concentrated discussions, and then, perhaps, to edit this discussion with high-level commentaries.

In this regard, IIASA might be interested in information about some user-oriented program systems that were made in CSSR:

a) system ORIOS, i.e. a package of programs for operations research and statistical methods and procedures directed by its own language; this system is open to other programs;

b) system SAPRO, i.e. a system for automatic building projection, statistical problems, and production control, directed by its own supervisor again; and

c) system for rayon-planning as a whole.

4. As to the proposal that "IIASA should begin with any concrete problem and solve it, "I fear, that in this way the research program on computer systems would split into the other projects of IIASA. I think that this interconnection of computer system activity with other problems is a matter of programming or of device or facility support of the IIASA computing center.

But I think that we can formulate our own research program in computer systems methods on the condition of the given staff of about ten to fifteen people a year.

Proposal: An example of such a research program on computer systems is described in my paper on "The System Approach to Computer Development" (Document U in these proceedings). This proposal may be linked with the proposal of Mr. Glushkov on forecasting of future development of computer systems, and perhaps also with the questions of computer (or computing) networks.

B. Artificial Intelligence

The state of art of A.I. in CSSR is currently a topic of extensive basic research and studies. Many papers and articles on pattern recognition and robotronics have been published. We have a project of a device for OCR where we developed the associated memory and known researching methods in that memory; we can translate a technical text from English to Czech. There exist three or four types of teaching machines (some of them all produced). On the field of the analysis and synthesis of the national language (Czech), there exist some works on coding the sounds in Czech, and equipment that pronounced Czech words was built.

Proposal: I do not endeavour to formulate any proposals but I mean that the problems of A.I. now are in the stage of extensive basic research and the applied problem solving in IIASA activities will be possible at a later stage.

C. Information Systems

In the world at this time, there exist many information systems applied on various computers (in CSSR there exist two such systems). It follows that IIASA's own new program of research work in information systems would duplicate and probably repeat the work done by other institutions, without regard to the fact that IIASA will probably not have sufficient manpower. But all the known solutions of information systems still have gaps--i.e. the problems of the effectiveness of these systems.

Proposal: I think IIASA should adapt any of the known information retrieval systems for its specific conditions. And, I think IIASA could, as its own research problem, solve the methodology of the evaluation of information systems.

D. Robotology

I have no remarks.

II. NATIONAL RESEARCH IN COMPUTER SCIENCES AND ARTIFICIAL INTELLIGENCE

Computer Sciences and Artificial Intelligence Research in Austria

Computer Sciences

Hardware: Dr. Wehrmann, University of Technology, Vienna
Stochastic Ergodic - Measurement technique.

Software:

1. Mathematical basis of simulation: Prof. Pichler, Lehrkanzel für Systemtheorie, University of Linz, Upper Austria (Input-Output Systems, Walsh Transformation, Fuzzy Systems).

2. Formal Definition of Computer Languages especially PL/I: Prof: Zemanek and his team, University of Technology Vienna, and IBM - Zebovalony.

3. Simulation of the Austrian Health System: Dr. Fleissner, Austrian Academy of Sciences.

4. Applications in the Biomedical Sciences at the University of Vienna Medical School. (Forecasting of the course of different diseases; analysis of EEG data by using multiple language interpolation and Walsh-Fourier analysis, modelling of electrophysiological functions (ER 6), information transmission in optical tract): Doz. Trappl with clinical co-workers. Other topics in computer systems in Austria are mentioned by Dr. Sint and Mr. Firneis.

Research Programs:

Institute for Advanced Studies, Vienna:
Econometric Modelling LINK Project.

Bundeskanzleramt:
Documentation of Law Cases concerning the Austrian Constitution.

University of Vienna:
Educational planning for Universities,
Management of Universities (Sint, et. al.)

Subroutine Control System (Winterleitner)

Different approaches to Cluster Analysis (Sint)
(Biological and social systems)

Question answering system for data basis using memory of results from answering previous questions (Stockinger)

Automatic Model Building (Gordesch)

Technical University, Vienna:
Universities of Graz and Linz:

Various projects in artificial intelligence, computer-aided instruction, simulation (e.g. Management games), University Management.

Artificial Intelligence

There are no large groups working in this field but individual work, on a large number of projects.

Some Examples

Representation of groups and its application to physics (Rastl)

Combinatorial Topology (Rennert)

Automatic Theorem Proving (Hacker)

Automatic Classification (Sint)

High level language question/answering system which remembers results obtained in answering previous questions (Stockinger)

Automatic Model Building (Gordesch-Sint)

Installation of Interaction Lisp--Compiler for theorem-proving (Firneis-Engelhardt)

Exploitation of noneuclidian geometry of human perception (Firneis).

Computer Sciences and Artificial Intelligence in F.R.G.

Artificial Intelligence

Pattern recognition:	Kaczunierczak, Karlsruhe Marko, Tech. Univ. Munich
Perception:	Mittelstadt, MPI Seeviesen (SFB 50)
World models:	vom Weizsäcker, MPI Hamburg
Associative memories:	Leilich, Braunschweig Billing, MPI Physics, Munich Scheder, T.U. Munich (SFB 49)
Semantic information processing:	Braun, T.U. Munich (SFB 49) H. Schneider, Stuttgart
Models for Behavior comparison computer/brain:	Matassek, MPI Psychiatry Munich (SFB 50) Aschoff, MPI Seeviesen (SFB 50)
Man-machine interaction:	Händler (Alanjan) Giloi (Saarbrücken) Schnichtke (T.U. Munich)

Computer Sciences

The Federal Government Program for the build-up of Computer Science runs under the heading:

> "Überregionales Forschungsprogramm Informatik des Bundesministeriums für Forschung und Technologie."

The universities involved are the Technical Universities of: Aachen, Berlin, Braunschweig, Darmstadt, Karlsruhe, Munich, and Stuttgart. Additional work is in progress at the Universities of Bonn, Erlangen, Hamburg, Kiel, and Saarbrücken.

Research in Computer Sciences and Artificial Intelligence in France

About Computer Science in General

Just a few names were mentioned, in selected areas of possible interest to IIASA;

- in the area of computer systems modelling: Dr. Gelenbe (IRIA) and Université de Rennes

- in the area of data base management and information retrieval: Dr. Abrial, in charge of the project Socrate at Université de Grenoble

- in the area of Theorem Proving and deduction systems: Dr. Huet at IRIA and J.M. Cadiou, also at IRIA

- in the area of natural language recognition and translation: Dr. Colmerauer at Université de Marseille.

About Artificial Intelligence

- in the area of automatic classification: Prof. Simon and Dr. Diday (Université de Paris - IRIA)

- in the area of character recognition:CNET (Center National d'Etudes des Télécommunications)

- in the area of theorem proving: Dr. Huet (IRIA)

- in the area of program correctness and automatic programming: a group at IRIA, and a group under Prof. Bolliet, financed by the branch computer manufacturer CII, at Université de Grenoble.

About Automatic Circuit Synthesis

- Professor Daclin at ONERA (Office National d'Etudes et de Recherches Aerospatials), Toulouse.

Ongoing Computer Sciences Research in G.D.R.

Efficient utilization of information processing in research, development, and design work depends on the availability of problem-oriented languages. These languages, their translation, and the whole associated pragmatic should be considered as part of a uniform programming and machine-operating system. The latter also supports the set-up and implementation of problem-oriented languages. An isolated draft and the constriction of a translator for each individual language is far too expensive. Several approaches may be used to master all these tasks: e.g. universal languages, compiler, compiling, extensible languages, meta-language concept for the formalized description of syntax and sematics of languages.

Special languages developed and implemented in GDR: Symap (language for numerical control of machine tools), Maus (measurement-oriented), languages for process control, simulation models, digital graphics, etc. (Technical University, Dresden (Mathematics), Academy of Sciences of the GDR, Berlin (Central Institute of Mathematical Mechanics), etc.

A meta-language system was investigated and implemented at the Technical University of Dresden (Mathematics). It assists the formalized description of syntax and semantics of problem-oriented languages and automatically generates a translation. (Syntactical description by extended B.M. Miles, for the description of semantic Algol-60--with special string handling--serves as a basis.) The system saves about 90% of the time of compiler writing. The research work includes formalized description of syntax and semantics of languages and pragmatic aspects within the associated operating system. (Academy of Sciences, Berlin: Central Institute of Mathematical Mechanics, Central Institute for Computing Technical University, Dresden: Mathematics).

Some Italian Research Institutions in the Field of Computer Science and Allied Subjects

Centres (financed by the Italian National Research Council--CNR--and a University or Polytechnic)

1. Centro per lo studio dell'interazione operatore-calcolatore (CNR-University of Bologne; director: Prof. De Lotto)

2. Centro per lo studio di sistemi di elaborazione dell'uniformazione (CNR-Milan Polytechnic; director: Prof. L. Dadda)

3. Centro di studio dei sistemi di controllo e calcolo automatici (CNR-Rome University; director: Prof. A. Ruberti. Prof. Ruberti is the chairman of the Italian Committee for Liaison with IIASA).

Laboratories and Institutes of the CNR

1. Laboratorio di Cibernetica, Arco Felice near Naples (director: E. Caianiello)

2. Laboratorio di Analisi numerica, Pavia (director: E. Magenes)

3. Istituto per le Applicazioni del Calcolo, Rome (director: I. Galligani)

4. Istituto per l'Elaborazione dell'Informazione, Pisa (director: G. Capriz)

Main Research Groups within Universities

1. University of Turin (Prof. C. Böhm)

2. University of Milan (Prof. Depli Antoni)

3. University of Pisa (Professors A. Grasselli, G.B. Gerace, F. Preparota, F. Luccio)

4. Other groups in Naples, Genoa.

Other Institutions

Centro Nazionale Universitario di Calcolo Elettronico, Pisa.
Director: A. Faedo (Italian Representative to IIASA Council)
Secretary General: G. Torrigialli

Centro di Studio per le Applicazioni delle tecnologie avanzate (C.S.A.T.A.), Bari.
Leader: Prof. A. Romano

Situation of Artificial Intelligence in Italy

1. Statistical Pattern Recognition and picture analysis and description

Prof. Palmieri:	(some time ago Prof. Gamba): PAPA machine (a PERCEPTRON-like recognizer), Istituto CNR, Camogli (Genova)
Prof. Grasselli:	picture description by linguistic techniques. IEI, v.s. Maria 46,56100, Pisa (also Prof. Montanari, same address)
Prof. Caianiello: and Prof. Levialdi :	neuronic networks and parallel picture processing. Laboratorio di Cibernetica del CNR, v. Toiano 2, 80072 Arcofelice.
Prof. Gallus: and Prof. Maccaro:	biological picture processing. Istituto di Biometria dell' Universitá, Milano
Prof. De Rosis:	biological picture processing. Istituto di Tecnologia Biomedica del CNR, v. Morgagni, 30/E 00161 Roma.
Prof. Meo:	speech recognition and synthesis. Istituto Galileo Ferraris, Corso D'Azeglio 42, Torino.

2. Semantic, Representation and Search

Prof. Montanari:	heuristic search, also with respect to operations research; semantic memories for learning; design and implementation of a language for AI (similar to PLANNER and QA4). IEI, v.s. Maria 46, 56100 Pisa.

Prof. Somalvico:	formalization of search. Istituto di Elettronica del Politecnico, via Ponzio 34/5, 20133 Milano.
Prof. Mariani:	Istituto di Elettronica dell' Universita, Padova) and Prof. Meo (see above) now beginning to work in AI.

Present Status of Artificial Intelligence Research in Japan

Hiroji Nishino

1. INTRODUCTION

Practical research on artificial intelligence in Japan has just recently gotten under way. Historically, since the end of the 1950s, the Electrotechnical Laboratory (ETL) has been engaged in the study of machine translation and optical character reader development.

However, due to technological immaturity, those early studies were unsuccessful. Therefore, in the 1960s, greater emphasis was placed on theoretical studies. For the development of the OCR, mathematical pattern recognition was studied, while computational linguistics was studied for machine translation.

Towards the second half of the 1960s artificial intelligence research in Japan became gradually active. In 1966 the ETL commenced a new R & D project for OCRs. This was also one of the subprojects of the "Super High-Performance Computer Development" Project that was part of the National R & D Program. As is mentioned later, the ETL, jointly with Toshiba (Tokyo Shibaura Electric Co. Ltd.), successfully developed an OCR, which was dubbed the ASPET/71.

Furthermore, in collaboration with the Tokyo Institute of Technology, the ETL Systems Research Group in 1967 started the development of a single hand robot equipped with a visual system.

As one of its main voice study themes for the 1960s, the ETL did extensive research into the synthesis of voice. By developing a vocal simulator, written sentences were fed in, successfully generating rather high quality speech.

With these R & D achievements in the background, the ETL launched in 1971 the "Pattern Information Processing System" Project. This project is very significant, since it is not only a large scale project concerning artificial intelligence research, but it has also helped make national artificial intelligence research familiar to the general public.

2. OVERVIEW OF ARTIFICIAL INTELLIGENCE RESEARCH IN JAPAN

It is somewhat difficult to sketch a reliable picture about the present status of artificial intelligence research in Japan because it is still in its infancy. Fig. 1 shows this research's general outline as the author sees it. (In the figure, a shaded mark means contracts awarded to industry in the PIPS Project.)

2.1 Fundamental work

In the table, "fundamental work" means theoretical foundations or preliminary studies on the artificial intelligence, although its true notion is ambiguous. It may include mathematical formulation of pattern recognition, problem solving (heuristic search, theorem proving, game playing etc.), AI language, automatic program writing and so on.

The research activities in this area are relatively weaker than those in the application-oriented areas. For example, Japanese research on AI language lags far behind foreign research. Several laboratories are now developing micro-PLANNER's. There is no original development of AI language. The only exception is FORMAL-2 developed by ECL. [1]

It is very interesting to note that the research on mathematical formulation of pattern recognition is active, in contrast to the development of software. The reason seems to come from the fact that researchers in this area do not have sufficient computing facilities.

2.2 Character recognition

Research on character recognition has a long history, covering a span of 15 years. Therefore it has been conducted in various locations and a large number of methods has been proposed. All the main frame manufacturers of computers are developing optical character readers. Several standard models of OCR are commercially available from Fujitsu, Hitachi, Toshiba and Nippon Electric (NEC). Among these, NEC is particulary interested in on-line character recognition on a terminal basis.

Fig. 1

Overview of AI Research

	fundamental work	character recognition	computer vision	robot implementation	speech recognition	natural language understanding
Universities						
Tohoku U.	O				O	
U. Tokyo	O		O	O	O	
Nagoya U.	O	O	O			
Kyoto U.	O		O		O	O
Osaka U.	O		O			
Kyushu U.						O
Tokyo Inst. Tech.	O	O	O	O		
Waseda U.			O	O		
U. Electrocomm.	O		O			O
Governmental or Public Research Institutes						
ETL	O	O	O	O	O	O
ECL	O	O	O		O	
MEL			O	O		
NHKL	O		O		O	
IPCP			O			
KDDL		O	O		O	
Research Laboratories in Industries (Main frame computer manufacturers)						
Fujitsu		●	O		O	
Hitachi	O	●	●	O	O	
Nippon Electric	O	O	O		●	
Toshiba	O	●	●	O		
Mitsubishi	O	O	●	O		
Oki Electric		O	O			

One of the best known applications in Japan is the automatic sorting of the Zip Code handwritten on letter envelopes or post cards.

Prof. Iijima, who was the former project leader of ASPET/71 described above, has energetically analysed conventional pattern matching methods and established his sophisticated mathematical theory. [2]

As a special circumstance of character recognition in Japan, there is the particularly important problem of the recognition of Kanji (Chinese) characters.

Our written language is usually a combination of Kanji characters and two kinds of Kana (Japanese alphabet) characters. Although there are many thousands of Kanji characters, about 2,000 characters are sufficient for daily use, while the minimum for educational use has been set at 881 characters. Each Kana alphabet (Kata Kana and Hira Kana) has 49 characters.

2.3 Computer Vision

Research on computer vision has two main objectives, namely, (1) improvement of man-machine communication and (2) manipulation or locomotion of an object.

Man-machine communication will be greatly facilitated if a picture of the real world can be directly fed into a computer. Most research laboratories in industries are attempting to develop several applications which will be of practical use. Some of these applications are the search for natural resources from aerial photographs, weather analysis from cloud maps, medical diagnosis from X-ray films and so on. Picture processing in this sense is usually application-oriented.

Prof. Sakai's group at Kyoto University has presented a contexed-controlled picture processing scheme for segmentation of the feature points and the programs based on the scheme. The interaction between the high level interpretation process and the segmentation of the feature points is used in the computer analysis of human faces. [3]

Recently Hitachi Ltd. developed a fault-inspection tester for printed circuit boards, which is now commercially available. It finds automatically the incompleteness of printed-circuits without the original circuit diagram.

As for 3-dimensional objects, extensive research on the recognition of polyhedras with various conditions have been performed at the ETL. The best performance in extracting line drawings from television images is given by Shirai's line finder. [4]

Prof. Tsuji's group at Osaka University is developing a special preprocessor controlled by micro-programs in order to reduce the processing time of recognition procedures. The group also presents a semantic-based decision method for texture recognition. [5]

2.4 Speech recognition

There are several approaches for speech recognition being taken in various laboratories in Japan, i.e. the zero crossing method at Kyoto University, the linear programming method at NEC and so on.

As speech recognition is a complex and difficult task, pessimistic views have become widespread. Therefore much more attention has been drawn to the linguistic aspects of speech recognition in order to rescue the technological immaturity. However, the importance of "parametric" representation of speech is still dominant.

One of the original projects on parametric representation in Japan is the partial auto-correlation coefficient (k-parameter) developed by ECL. [6] This resulted from one of the adaptive filtering techniques. Voice recognition for numerals using the k-parameter will be applied to the telephone service.

Recently the ETL has succeeded in estimating the vocal tract area functions by analysing natural speech waves. The mouth shape when speaking (area function) would be the most effective parameter. Now variations in mouth shape can be obtained accurately for connected natural speech. [7]

2.5 Robot Implementation

In Japan there are more than 200 manufacturers developing industrial robots, while there are few laboratories in which intelligent (universal) robot research is being actively conducted.

A typical example of robot research is the Wabot 1, which was developed at Waseda University. It has an artificial ear (microphone and voice recognizer of terminal analog type), mouth (speaker), eyes (2 TV cameras), arms with fingers (manipulators with tactile sensors) and legs with walking mechanisms. It is about 2m high and weighs 160 Kg. Unfortunately the individual parts are often not up to expectations.

One of the main interests of robot research is the development of visual systems. Beside the projects categorized by computer vision, several pragmatic approaches have been reported. The ETL has developed two kinds of range finders. A range finder employs a vertical slit projector as a light source and a TV camera as a receiver. The distance to each point is obtained by means of trigonometrical calculation. A laser trucker system consists of an He-Ne laser and an image dissector. Range information is obtained directly by the reflected laser beam.

Recently Drs. Kobayashi and Seko at Waseda University have developed a parallel image processing device utilizing the recovery characteristics of a channel plate multiplier. It can extract the boundary of objects in ns order.

The greatest efforts in robot research are being devoted to the control of manipulators. The ETL-HAND is a hydraulically-driven, multi-joint manipulator having six degrees of freedom, three for rotation and the other three for pivot-action. It has been designed with special attention paid to efficient control.

As for tactile sensors, Prof. Kato's group at Waseda University has developed a tactile sensor with small beams and a strain gauge. This sensor is developed primarily for prosthetic applications and displays a favorable similarity to the sense of touch of human fingers.

A small mobile robot which has been developed by Dr. Sato's group at the ETL has a manipulator with 36 tactile sensors using special contact-switches. Furthermore it has an additional 16 tactile sensors on the peripheral section for guidance of the locomotion.

The Hitachi Central Laboratory has been developing several kinds of hand-eye systems, named HIVIP I, III, V and VII . The recently developed HI-T-HAND EXPERT is an industrial robot with tactile sensors, which can skillfuly fix piston rods into cylinders.

3. PATTERN INFORMATION PROCESSING SYSTEM

A research and development project entitled "Pattern Information Processing System (PIPS)" has gotten under way for the eight-year period from 1971 to 1978, and is funded at ¥35 billion.

This ambitious project under the National R & D Program (NRDP) is one of the largest projects in our country and is directed towards artificial intelligence research.

3.1 Outline of the Project

The present research activities are divided into the following three areas:

(1) development of new materials and devices which may be applicable to pattern processing,

(2) studies of subsystems for recognizing such visual and aural patterns as characters, pictures, 3-dimensional objects and speech,

(3) development of information systems having such new capabilities as parallel processing, associative information retrieval and inference or learning.

The activities in each research area are closely related to each other. It is the final goal of the Project to construct a prototype system referred to as PIPS, which will be able to integrate the accomplishments obtained in each area.

The interrelations among the research areas, several kinds of pilot models and a prototype system are illustrated in Fig.2.

However the final aim of the Project is not only to construct a specific system, but also to develop advanced technologies of pattern information processing. The Project may not achieve all its stated objectives, but it is expected to give some important contributions to the future information processing field.

The basic and internal studies in the Project are conducted by the ETL. Contracts to industries are awarded by the cooperative acting of the AIST (Agency of Industrial Science and Technology) and the ETL. Beside these studies, the

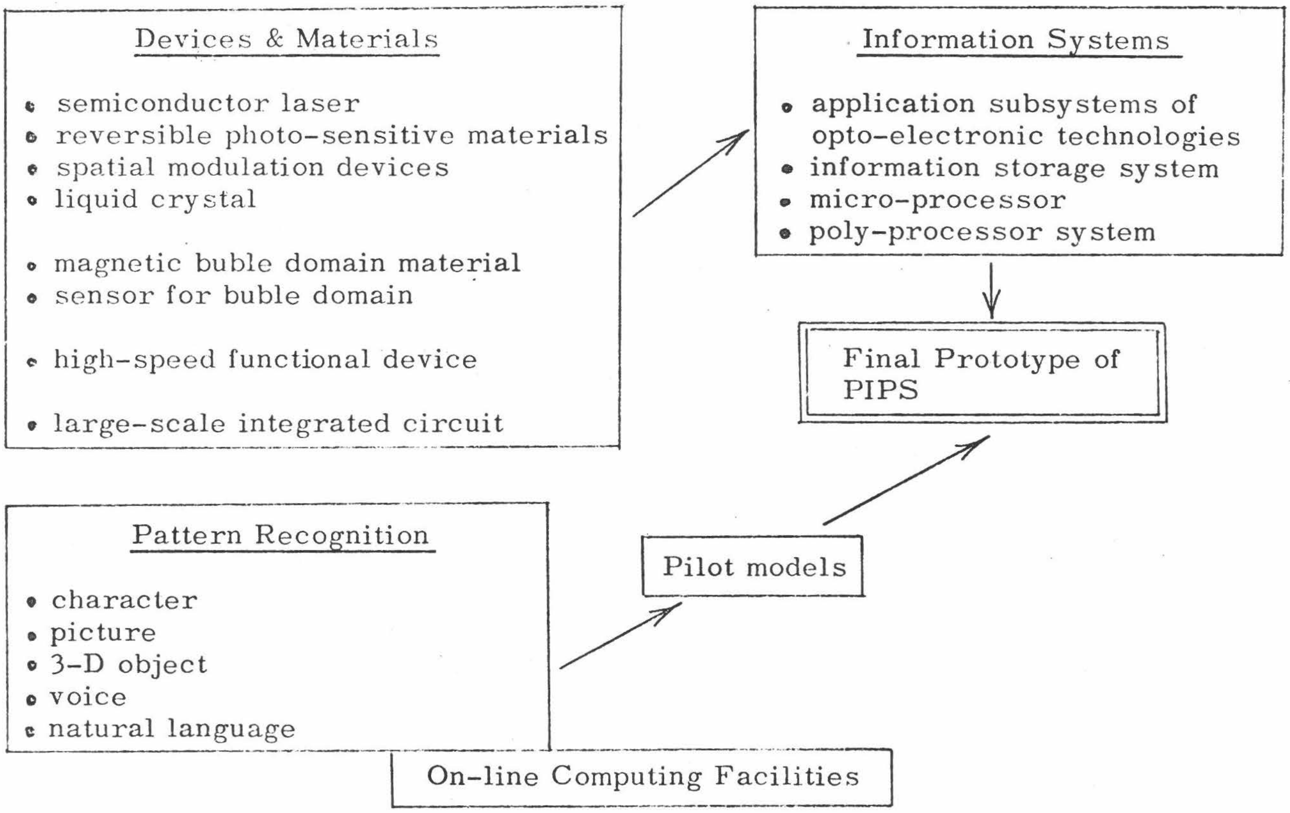


Fig. 2 Research Areas of PIPS

important role of the ETL is the coordination and the technical supervisory of the whole project. Participation by university researchers is tertiary in nature.

The total investment during the eight-year period is roughly estimated to be ¥35 billion. Fig. 3 shows the long-term schedule and the budget of PIPS Project. These figures of the budget in the future, however, indicates merely the upper limit of the first approval of the long-term program from the Ministry of Finance (MOF). The annual budget is requested to be approved by the MOF every year.

(Million yen)

		1971	1972	1973	1974	1975	1976	1977	1978
1. Pattern Recognition Systems									
1.1 Subsystems for;									
(1) Character Recognition	ETL	29.5	78.3	77.8					
	contractors			93.0		Pilot Model			
(2) Picture Recognition	ETL	23.1	57.7	89.9					
	contractors			159.8		Pilot Model			
(3) 3-D Object Recognition	ETL	13.7	65.0	75.0					
	contractors			17.9		Pilot Model			
(4) Voice Recognition	ETL		51.9	68.3					
	contractors			18.7		Pilot Model			
1.2 AI Language and Natural Language understanding	ETL	21.6	80.3	76.7					
	contractors								
2. Materials and Devices	ETL		111.6	160.7					
	contractors	77.8	264.9	545.4					
3. Information Processing System	ETL	24.6	323.2	473.7					
	contractors			31.3 Pilot Model					
4. Planning and Consolidated System-Prototype	ETL	6.0	14.7	20.2					
	contractors					Prototype System			
Total		196.2	1,047.6	1,908.5	3,900	6,400	8,400	8,200	3,700

Note: ETL: Electrotechnical Laboratory

Fig. 3. Schedule for Development of Pattern Information Processing System

3.2 Research Activities of the Project

Character Recognition

The main objective of character recognition is to develop a Kanji character reader by discovering a practically useful algorithm. The specifications required are as follows:

(i) Character repertoire
Kanji characters in daily use, two kinds of Kana (Japanese alphabet) characters, alphanumeric characters and symbols (more than 2,000 characters)

(ii) Printed quality
Better than or equal to that of a newspaper

(iii) Rejection rate
Less than 10^{-3}

(iv) Substitution rate
Less than 10^{-4}

The following several approaches, i.e., the

Field effect method
Angular distribibition method
Multi-stage decision method
Hierarchical matching method
Peripheral distribution method
Pairwise comparison method

have been evaluated by computer simulation at the ETL, Hitachi and Toshiba. One of these will be reported at the 1st International Joint Conference on Pattern Recognition.

Fujitsu Ltd. is now taking up the recognition of handwritten characters.

Speech Recognition

The purposes of the speech recognition research are: (a) the minimum to develop and evaluate a pilot model of a speech recognizer and (b) to develop a more advanced algorithm of speech recognition and to establish the techniques required for the design of a proto-type model.

The specifications required for the first pilot model are as follows:

(i) Number of words to be identified
Predetermined vocabulary of about 200 words or more spoken in isolation

(ii) Speaker
Several persons specified

(iii) Environment
Low noise environment (normal noise condition in an ordinary office room)

(iv) Response time
A few seconds, possibly in real-time

(v) Recognition rate
98 % or more

NEC, contractor of the pilot model, is now adopting a pragmatic approach and is engaged in the development of "Limited Vocabulary Speech Recognition using Dynamic Programming". Efficient data reduction algorithms based on optimal linear transformations in the spectral domain are being investigated.

The ETL is busy attacking more fundamental problems. Namely, the main concern of the ETL group is to find better parameters, as well as to establish better schemes for inclusion of linguistic aspects. As for new parametric representation, the ETL group has already achieved the breakthrough as described earlier.

The mouth shape at utterance which is directly derived from speech waves would be the most effective parameter. The problem, however, has not been solved effectively, because it includes deconvolution of vocal tract characteristics and sound sources including the radiation characteristics. The ETL group recently discovered a powerful method for deconvolution. It will therefore be possible to obtain the vocal tract shape in real-time with a special purpose hardware.

Computer Vision

As described in the previous section 3.1, the Project aims at the research and development of recognition of both picture and 3-dimensional object. Although their purposes and approaches for picture processing and scene analysis respectively are slightly different to each other, these two research themes are collectively described in the same frame as computer vision.

The objectives of both research themes are:

(a) to develop the high precision visual input equipment,

(b) to develop recognition algorithm and software and to make pilot models demonstrate the result of these research and development, and

(c) to establish effective techniques for constructing prototype models.

The detailed specifications of pilot models are not yet given except for visual input equipment.

The Toshiba, contractor of the visual input equipment, is now developing a high resolution double deflection CRT.

Three contracts were awarded to the Toshiba, Hitachi and Mitsubishi. However the research activities of computer vision rely, at the present time, solely on that of the ETL because these contracts were awarded just in this year.

At the ETL, several methods for extracting feature points have been developed. Dr. Tojo's group has developed an experimental array preprocessor for binary picture processing. It has 16 × 8 processing elements and has supporting software which enables it to process larger input data.

As described earlier, Dr. Shirai's line finder has good performance in extracting line drawings from television image. It first finds the outer boundaries of an object and cluster of objects. It then tries to guess additional lines that are extensions to lines already found. The program is based on the strategy of recognizing objects step by step, each time making use of the previous results. At each stage, the most obvious and likely assumption is made and tested.

It is well known that range information greatly simplifies the interpretation of scenes. Several range finders have been developed.

The Toshiba, aims at the development of technology for analysing and interpreting aerial photographs. It is intended for more effective use of land and natural resources.

The Hitachi Ltd. intends to develop automatic manipulation of goods information in future distribution systems.

The main interest of the Mitsubishi is the processing of colored pattern.

Research Facilities

The Electrotechnical Laboratory's Pattern Information Computing Systems (EPICS) provides sophisticated computing network facilities for pattern processing research projects. Specialized research groups are attempting to concentrate their research efforts on refinement of the facility for use in common high level processing among groups.

Within a highly interactive environment, researchers may perform complex information processing, probe the man-machine interface, input remote data for analysis, develop the most modern pattern recognition techniques, and verify the visability of techniques.

In order to achieve a maximum processing versatility, the EPICS is a totally integrated network composed of various specialized systems. The main-computer, a TOSBAC-5600, is capable of digital high rate (64 KW/s) communication with any other sub-computers or terminals, and provides extendable language ALGOL-N and A.I. languages such as LISP, micro-PLANNER and data base functions. The TOSBAC-5600 has a remote job entry, 8 CRT character displays and 16 CRT graphic terminals used for TSS basis.

All of the sub-computers have local graphic display systems which enable researchers to monitor how the data processing is getting on. In addition to conventional peripheral devices, including magnetic disk units, each sub-computer has information processing accessaries corresponding to its particular research field, as illustrated in the figure.

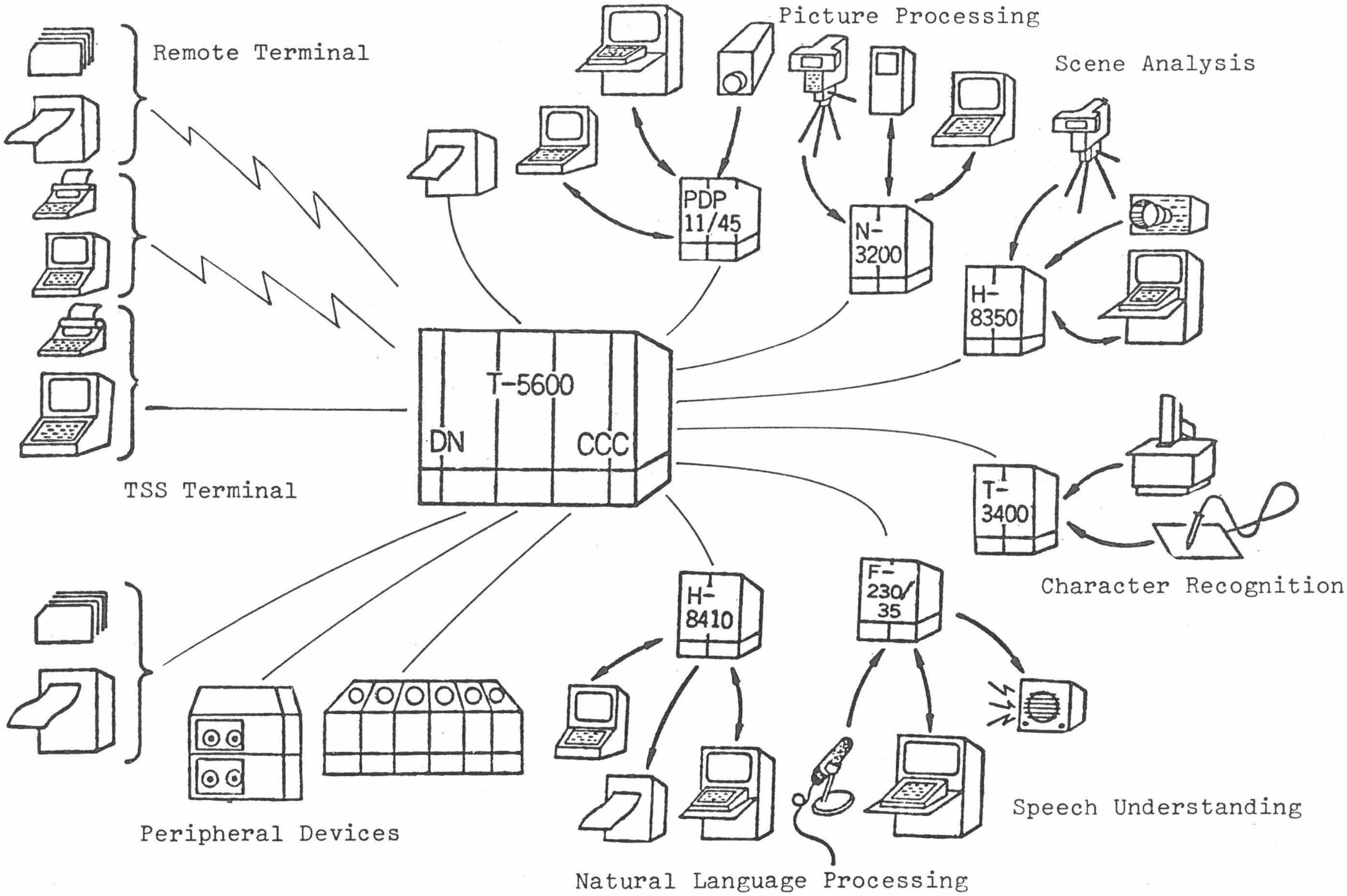


Figure 4. Research Facilities (EPICS)

The PDP-11/45 mini-computer has an image scanner for picture processing and has a Rainputto Keyboard to be used for Kanji input to EPICS. The NEAC-3200 mini-computer has various types of self-developed graphical input/output devices to input/output graphical data and is used for their low level processing. The TOSBAC-3400 has a flying-spot scanner capable of reducing a frame film strip to digital data and is used for research in character recognition. The HITAC-8350 has a range finder using a slit beam for use in scene analysis. The FACOM-230/35 has a speaker and a microphone used for speech understanding research.

Any of these sub-systems connected to the main-computer can be communicated to each other or used on an opportunist basis to give access to distributed files, devices and processes.

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Note:

Tokyo Inst. Tech. = Tokyo Institute of Technology

U. Electrocomm. = University of Electrocommunications

ETL = Electrotechnical Laboratory, MITI

ECL = Electrical Communication Laboratory, NTT

MEL = Mechanical Engineering Laboratory, MITI

NHKL = Broadcasting Science Research Laboratories,
and Technical Research Laboratory,
Nippon Hoso Kyokai

IPCR = Institute of Physical and Chemical Research

KDDL = Research and Development Laboratory,
Kokusai Denshin Denwa Co. Ltd.
(Japan's Overseas Radio & Cable System)

o

MITI = Ministry of International Trade and Industry

NTT = Nippon Telegraph and Telephon Public Corp.

KDD = Kokusai Denshin Denwa Co. Ltd.
(Japan's Overseas Radio and Cable System)

NHK = Nippon Hoso Kyokai
(Japan Broadcasting Corporation)

Present State of the Artificial Intelligence Research in Poland

Juliusz Kulikowski

Artificial Intelligence has a comparatively long tradition in Poland. For many years great attention was paid to the pattern recognition problem. In particular, some statistical and geometrical models of classification were intensively investigated, as well as their practical application in medicine and technology. During the period 1961-70 the activity in that area has increased, and now the investigations are concentrated on several problems of great practical importance.

In the Polytechnical University of Poznan a small group is still working on the problem of computer proving of mathematical theorems. A similar problem is also solved in the University of Lodz.

The problems of human voice synthesis are solved by a group headed by Prof. T. Kacprowski in the Institute of Basic Technical Problems of the Polish Academy of Sciences in Warsaw. However, the approach represented by this group does not include the semantical aspects of the problem.

The problems of pattern recognition are investigated in two main aspects:

1) mathematical models of medical diagnosis, and

2) automation of experimental data processing and their interpretation.

In both cases the recognition of patterns is considered as a part of some more complicated problem (the medical care, the experimental research, etc.)

The problems of mathematical models of medical diagnosis are being investigated in several organizations. In particular one should mention here:

- the Medical Academy in Silesia, concentrated on some internal diseases (diabetes);

- the Pedagogical Institute in Warsaw, where an interesting research concerning the logical prognosis in heart diseases (as well as in successful studies of the first-course students) has been performed under the supervision of Prof. W. Okon;

- the Institute of Applied Cybernetics of the Polish Academy of Sciences in Warsaw, where interesting results have been reached in the field of automated diagnosis of some kinds of throat diseases of children, the methods being based on an analysis of the respiration noise.

Since the results reached were of practical importance, the interest in them is great despite the fact that they were obtained using comparatively simple mathematical models.

The problems of experimental data processing and interpretation lead, on the other hand, to much more sophisticated theoretical problems.

The group headed by Dr. R. Gawronski in the Institute of Applied Cybernetics of PAS in Warsaw investigates the possibilities of artificial neuronal nets in classification of signals. The problems of motion systems (including the celebral processes and effectors reaction) modelling are also the point of concentration of this group.

A structural approach to the visual data interpretation is developed in the group headed by Prof. J. Kulikowski in the Institute of Applied Cybernetics of PAS in Warsaw. The experiments are performed on a picture processing system consisting of an image-coding automatic (using a TV camera) connected on line to a digital computer ODRA 1204. Several versions of picture processing languages (Picture ALGOL) has been elaborated there and are used now in the experiments. The experiments are made in close cooperation with several medical and biological scientific groups. The goal of that research concerns the improving of the methods used in examination of microscopic photographs, radiograms, diagrams, etc. The formal linguistic approach is used on the higher levels of structural analysis of the pictures leading to their semantical interpretation.

Fundamental research of non-classical logics application in some problem oriented languages is also going on in the same group. In particular, the application of Prior's tens logic in some observations research problems are investigated. Some attention has been also paid to the typological logics considered as a tool for the examination of undetermined situations occurring in pattern recognition. There is a great interest among the Polish scientific groups in the possible international cooperation in the above indicated areas. However, it is being hoped that the IIASA's activity in Artificial Intelligence should be restricted to some well-determined problems of great practical importance and closely related to the other IIASA's projects.

Artificial Intelligence in U.K.

1. Edinburgh - School of AI
   a) D. Richie's group (Popplestone, Barrow, Salter)
      hand-eye robotics, chess programs
   b) B. Meltzer's group (Kowalski, Bundy, Moore)
      computational logic and theorem proving
   c) R. Burstall and G. Plotkin
      theory of computation
   d) H.C. Longuet-Higgin's group (Isard, Davies)
      natural language semantics
      the POPLER language.

2. Sussex University
   M. Clowes, scene analysis and representation for knowledge.

3. Essex University
   P. Hayes, robot logic, and high level languages.

4. Aberdeen University
   E.W. Elcock, automatic programming
   (P. Gray, collaborator).

Artificial Intelligence in the USA

There are several large laboratories, with funding over $1 million per year for AI related work. Three of these are concerned with almost all AI problems:

Stanford University
Stanford, California
Feigenbaum, Feldman, McCarthy

M.I.T.
Cambridge, Massachusetts
Minsky, Papert, Winston, Hewitt

Stanford Research Institute
Menlo Park, California
Nillson, Raphael, Rosen, Waldinger

Major centers with more limited domains include:

Harvard University Cambridge, Massachusetts Cheatham, Wegbreit	AUTOMATIC PROGRAMMING
Information Sciences Institute USC Los Angeles, California Balzer, London	AUTOMATIC PROGRAMMING
Carnegie-Mellon University Pittsburgh, Pennsylvania Newell, Reddy	SPEECH, HUMAN COGNITION

Other significant efforts include:

Bolt, Beranek and Newman Cambridge, Massachusetts Woods, Rovner	SPEECH AND LANGUAGE
University of Texas Austin, Texas Bledsoe, Simmons	LANGUAGE AND FORMAL METHODS
Xerox Park Palo Alto, California Bobrow, Teitelman, Deutsch	LANGUAGE AUTOMATIC PROGRAMMING

Case-Western Reserve Cleveland, Ohio Banerji, Ernst	FORMAL METHODS
Rutgers University New Brunswick, New Jersey Amarel	HEURISTIC METHODS
Syracuse University Syracuse, New York J.A. Robinson	FORMAL METHODS
University of California San Diego, California Norman, Rumelhart	NATURAL LANGUAGE AND MEMORY
IBM Research Yorktown Heights, New York Pat Goldberg, Petrick, Will	Most areas

Computer Sciences and Artificial Intelligence in U.S.S.R.

Computers and Systems

1. Institute of Control Problems, Moscow.
   Prof. Aven

2. Institute of Cybernetics, Academy of Sciences of the Ukranian SSR.

3. Institute of Applied Mathematics, Academy of Sciences of USSR, Moscow.
   Prof. Mamlin

4. Computer Center of Siberian Department of Academy of Sciences of USSR.
   Prof. Ezshov

Automated Design

1. State Committee of Sciences and Technology of USSR, Moscow.
   Prof. Pameev

2. Institute of Control Problems, Moscow.
   Profs. Gavrilov and Zipkin

Artificial Intelligence

1. Institute for Applied Systems Analysis.
   Prof. Ahazimski

2. Institute for Problems of Information Transmission.
   Profs. Maximow, Stefanjuk, and Veinzveig

3. Institute for Physical Engineering.
   Prof. Kusin

4. Computer Center of the Academy of Sciences.
   Prof. Pospelov

III. APPENDIX

Comments on the Automation of Logical Synthesis
(With Emphasis on Industrial Applications)

E. Daclin
ONERA, Toulouse, France

It is remarkable to see that logical synthesis, properly speaking, comprises two or three quite distinct domains--much more distinct, at any rate, than a decade ago. The first domain is that of components. By way of illustration, one could say that the classic electronics man (formerly a specialist in tubes, and then more recently, in transistors and diodes) has given way to the solid state physicist who designs a range of integrated circuits. The second domain is that of the design of sub-modules of specialized logics. The engineer charged with this work is not necessarily a specialist of components or of electronics, but must above all be a logician in order to define well the procedures of implementation, of tests, etc. Finally, one can think of a third domain, that of utilization--whether one speaks of automated industrial processes, or of computer hardware. The number of engineers who are neither electricians nor physicists who must deal with such problems is increasing.

Let us illustrate this classification with an example. A firm wishes to automate the start of a production unit consisting of several possible sequences according to the type of product made. The production engineer goes out to find a manufacturer of computers or of automated processes to ask him to define and to make the appropriate material. The engineer of this second firm will have the task--using the sub-modules existing in his catalogue--of defining completely the necessary system of automation to resolve this particular problem. In fact, the situation is a bit more complex since, if certain sub-modules are manufactured by this firm, it will purchase the basic components directly from a component manufacturer. One might even attempt (in the case of repetitive equipment) a complete integration of the system. In computer firms, the first two functions (corresponding to the definition of software and hardware) are generally fulfilled within the same company. For certain of these firms, the finishing of the integrated components even forms a part of the factory.

Automation of the logical synthesis thus enters the picture at these three stages, and for each poses essentially different problems. Obviously one cannot deal with these problems in a few pages. Thus the aim of these comments is basically to propose a few ideas.

We can begin rather generally by saying that the complete automation of some process of synthesis seems far off. Consequently, we feel it is more a question now of defining the means for an "aided," rather than "automated," design.

From our experience with problems of components, we are inclined to think that the first step to take lies in a finer mathematical representation of the physico-chemical behavior of the components used (identification in the sense used by the automatician in order to simulate their behavior on a computer (for example, according to the placement or thickness of such and such a layer of such and such a product). In this context, the mathematical techniques to be used arise from the identification of systems with shared parameters (and thus governed by partial differential equations). A second axis of effort concerning the components is that of aiding design and all the associated techniques. In contrast to the first point, I feel that much work has been done in this or related areas which will soon bear fruit.

For problems of specialized logical groupings, there are two types of tools currently being used. These are either theoretical approaches--limited rather quickly by the scale of calculations they necessitate--or "heuristic" approaches--hard to transfer from one person to another. Here again, the task is one of producing programs to aid design which permit the designer to define in simple terms (e.g. blocks, interconnections) the circuit he wants to build. The built-in algorithm(s) of synthesis give shape to a circuit whose functioning the designer wishes to simulate by different sequences. It would be desirable for the test and breakdown simulation procedures be included in these packages. We know that such packages have been conceived at this time, but we think these are most often unwieldy and insufficiently conversational (interactive).

Finally, we have the problem of the user--the last or first link in the chain. In many respects his problem is the same as that of the manufactuerer of logical systems in that he is the one who is posing the problem. In our opinion, however, two essential differences exist between the two. On one hand, the logician--the manufacturer of the logical modules--is much more directly affected by the technological aspect of the problem (stress of supply, use of positive or of negative logic, etc.). On the other hand, one could say that, by definition, the user--the client--is someone who can know nothing about logics: the only thing which one can ask of him is that he be capable of clearly defining the system he wishes built. Under these conditions, once can consider that a particular effort should be made to conceal from him all the purely technological problems, as much at the level of elaborating a circuit as at the level of maintenance, as these will be the concern of the designer.

These are the broad outlines which we feel are desirable. Are there instruments we can make to arrive at these results? In the area of component production, we are, as we have said, still waiting for techniques to study of shared parameter systems. In the area of the design of logical submodules, we think that a language common to logicians and to non-logicians alike exists, and that its properties and extensions are worth deeper study: we are speaking of Petri networks. As shown in the description of work at the DERA below, this technique offers several important advantages. It is a means of simple description; it permits rapid progression to implementation. Furthermore, it lends itself to a "hierarchicalized" conception: one defines macroblocks, and one can then decompose them in turn and handle them with analogous techniques. It is a language which can be common to specialists of both hardware and software. From this approach, one can finally simulate different possible decompositions of the same system. (We have, incidentally, begun some modest studies on this subject, but I will not go into them in this paper).

Overview of Work at the Department of Studies and Research in Automation (DERA), Aerospace Complex of Toulouse, France

Since 1967, the Department of Studies and Research in Automation (DERA, formerly CERA) has been interested in the automatic synthesis of asynchronic automated industrial processes.

In industry, the design of automated processes remains largely empirical. The theoretical methods rapidly become inapplicable to industrial processes whose scale and complexity have little to do with the examples "selected" by the theoretician. Theory (methods and tools) has not kept pace with the needs of the practitioner. In particular, the forward leap of technology (cost of components, large scale integration, etc.) has been considerable: sophisticated methods permitting us to "gain" an internal variable no longer have any interest for us.

Furthermore, expenditures for "studies," "tests," and "documentation" represent more than fifty per cent of the cost of a piece of equipment, and this proportion is tending to increase. This means that the most significant gains will be obtained at the level of methods of conception, of testing and of maintenance--hence the interest in automation of these phases (or, rather, in an aid to conception).

Ongoing Work

1) In a first study contract DGRST (70 7 2373) which led us to collaborate with an industrial firm, Télémécanique Electrique, we have brought to fruition a program of automatic synthesis of asynchronic sequential circuits (SACADO):

a) In the contract specification the function of the automated process is described by a graph linked to the organigram ("process graph").

b) The SACADO program effects the following phases: search for the E/S sequences, Indexing of Regular Expressions (Glushkov,) simplifications of indexing, coding (Tracy), equations and simplification of the functions (method of zeros), outline of the relay diagram.

The classic methods of synthesis which we have employed in this study are rapidly proving inapplicable to automated industrial processes for multiple reasons:

a) They must be put into a form that is fairly far removed from the contract specification (process graph) and often difficult to obtain according to the type of problem involved.

b) The growing complexity of automated processed does not allow consideration of problems as a whole (there is a priori reduction into smaller subsystems).

c) Finally, the end result (based upon an obsolete criterion of minimizing the number of internal variables) loses all physical meaning and increases the difficulties of testing and maintenance.

2) In a second study (DGRST contract number 71 7 2913),

also in collaboration with Télémécanique Electrique, we gave ourselves two goals:

a) to seek out methods of synthesis which from the start of the synthesis process allow determination of a structural or technological decomposition of the system. For this, we sought to return as closely as possible to the contract specification and to free ourselves from representations by unwieldly tables; and

b) to achieve a modular realization of the automated process in order to facilitate maintenance and repair (in effect, under the criterion of cost, the "study" and "maintenance" areas are preponderant over the "components" area. Thus one is determining a (or some) modules and a (or some) method (s) of synthesis which allow us to obtain the modular structure of the circuit starting from a description of the functioning of the automated process.

The foundation for the conception of an automated process is the detailed contract specification. The descriptive tool often used in industry is the organigram; we have formalized it using Petri networks.

In addition, we have been interested in a modular design based upon the use of command modules operating on a question-answer format. A numerical program for simplifying the Petri networks has been written in order to obtain a reduced (but we do not say minimal) modular realization of the machine.

This original approach to synthesizing automated industrial processes has several advantages:

a) The Petri networks constitute the only document in the process of synthesis (from the contract through implementation). Use of the networks is simple and flexible, thus permitting a representation of the parallel functioning of the systems. The networks also introduce the important notion of machine receptivity to a class of events.

b) The simplification of the Petri network, based upon a decomposition into subgraphs of state, requires the support of supplementary information; this is necessary for the reduction into subgraphs (the finer the description of the functioning of the machine, the greater the simplification possible).

Additionally, in the course of this simplification, we are seeking to retain a physical sense in the Petri network as a valuable aid to understanding the modular set-up, the maintenance, and the repair.

Finally, the completed module design (five types of command modules) retains the structure of the Petri network, and is thus close to the contract specification.

Within the framework of this contract, a logical modulator simulator (five types of command modules) was conceived and completed in collaboration with Télémécanique Electrique.

3) From the results obtained during this study, and from the tools developed, we plan to continue our work, ending with the preparation of prefabricated subgroups allowing construction of specific and/or programmable and/or linkable installations. The diversification necessary for the best use of the methods and modules already achieved will thus be assured.