COINS Cybernetics Group/Center for Systems Neuroscience
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<u>COMPUTER PLANNING DOCUMENT</u> (January, 1975)

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| 1. | Deductive System | - Fishman |
| 2. | VISIONS System | - Ehrich, Hanson, Riseman |
| 3. | Neural Net Systems | - Arbib, Karshmer, Kilmer, Lenherr, Spinelli |
| 4. | Neurophysiology | - Spinelli, Lenherr |
| 5. | AI/Neural Hybrid | - Arbib, Kilmer |
| 6. | Parallelism in AI Languages | - Arbib, Fishman, Riseman, Soloway |
| 7. | AI Learning | - Kilmer, Soloway |

1. Fishman helped build the Maryland deductive system. He studied a kinship data base system with ~400 assertions and 100 general axioms. Using older methods, solving 1 problem required 15 msec to 1 minute CPU time. Using Fishman's improved methods, the CPU time for the hardest problem was reduced <u>from 1 minute to 2-1/2 seconds</u>.

He is now building a more powerful deductive system, which uses theorem-proving techniques, refined search strategies, and semantics. His principal research interests focus on two main goals. One goal is to devise concepts and methods to facilitate the application of deductive methods to large data base information retrieval problems. An approach he is currently investigating involves the use of problem solutions learned during search to dynamically adapt a data base so as to more efficiently respond to frequently posed question types. Another goal is to investigate and develop methods for making the power of the deductive system an available and controllable feature of a programming language. The idea is to make available a large data base with a superimposed hierarchical structuring capability and the efficient goal-directed search mechanism of the deductive system to a problem-solving system implementor. The system implementor can either rely completely on the search mechanisms provided, or he can access and control them to the extent he deems necessary. Fishman views such a language as an advance with respect to other AI languages because of (1) the large data base capability; (2) the data representation and deductive syntax (Π-representation) to be employed; and (3) the availability of a powerful search procedure which may be controlled to any extent desirable.

The first application of the deductive system will be to a 1000 assertion data base for the Riseman-Hanson vision system, with a planned expansion to 10,000 assertions over the next few years. To provide perspective on general deductive techniques, he would welcome a second large data base via SUMEX-AIM--e.g., a suitably restricted base for medical diagnosis.

| | Core | | Disc | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| Data Base | x | x | 5K | 50K |
| Program and Search Space | 65K | 150K | 100K | 200K |

Figure 1

Projected Space Requirements for the Deductive System

The handling of short bursts will require dynamic memory management. Much of the maximal disc load could be handled by roll-in from magnetic tape.

The data base comprises a dictionary (which has allowance for overhead, semantic information, etc.) and an assertion space with pointers from dictionary items (objects, attributes, relations) to the assertions in which they occur.

2. The VISIONS system has two parts
   A. The Preprocessing Cones
   B. The Scene Analysis System

A. The preprocessor (simulating a parallel layered structure) is implemented on a PDP-15 (32K core, 18 bit words) supplemented by a 1M word disc, a mag-tape, plus a DEC-tape. Graphical display is on a VT-15, with added joy stick control to focus on regions of a 256 x 256 scene. The display is poor--40 x 40 is the limit for viewing 30 gray levels (built up from 8 levels per micropoint). We can retrieve arrays from disc, process, focus, threshold, etc. We are building (for March 1 completion) a color monitor, 9 times faster than core, which will allow us to refresh and update a 64K array with 8 levels in 3 colors (i.e, 64K x 9 bits).

The cone preprocessing is resident in the PDP-15, and converts a 256 x 256 scene into 1/2M words of cone data (including raw data). A simple cone (e.g., averaging up to the 16 x 16 level) may take only 20 seconds on the PDP-15; a complex cone (e.g., iterated processing up and down the cone for line-finding or texture segmentation) may take as long as 25 minutes. (Funding may be sought to place more preprocessing in parallel on hardware.)

This process could be made available to other SUMEX users. Noting that TYMNET is 300 baud, it would take about 2 hours to transmit a 3-color scene over TYMNET without using image compression. If funds were available to develop a 2400 baud channel, a 20 minute transmission would become feasible. The 15 is not currently accessible by telecommunication. Funding would be required for this--including setting up of a command language for other users to have data preprocessed by remote control in off-peak hours. (It requires about 3 hours of both "setup time" and machine time on the 15 to transform a raw scene into formatted cone output on tape. We would be limited to perhaps 1 such service per week without remote control, or funds for an off-peak operator. Direct tape-mailing may be most practical. We could investigate the possibility of setting up a time each day for remote typing in of control cards, with processing during off-peak periods.)

The cone preprocessing could be used by labs involved in blood-cell, chromosome, or cancer-cell analysis. However, our lab will use it for scene analysis.

Research in image processing and scene analysis from a system theoretic point of view is being conducted by Ehrich. At the present time, he is developing edge detection algorithms for images containing edges of low curvature and which contain vast amounts of noise. His present work is currently applied to detection of earth faults in single band ERTS satellite imagery. Because of the large number of points in such images, he has not yet been able to do multispectral work, which is an important extension of his current work. He has recently completed construction of a monochromatic optical scanner with 25 micron resolution, and is beginning to work with more general applications of his techniques. Also, he anticipates applying edge detection algorithms to the digital topographic map data that is now becoming available from the U.S. Geological Survey.

Ultimately, these edge detection algorithms will have to be semantically directed, though in initial work, edge and line semantics are being embedded mathematically in a dynamic programming algorithm. In its early stages, the edge detector is not making use of texture boundaries, though the algorithm could easily make use of such information. Therefore, Ehrich will be working on the texture boundary detection problem. In any case, his system is currently designed for the PDP-15, but even in its initial stages, it requires all storage available on that machine.

B. The next stage of the VISIONS system requires the development of scene analysis of outdoor scenes. The scene is analyzed into objects, with a data base containing $\sim$20 attributes per object as well as 20 relations involving an object used to place it in context during model-building. The prototype will involve scenes made from 10 objects. The next few years we will seek an expansion to $\sim$200 objects and $\sim$8,000 assertions.

The scene analysis system will use Fishman's deductive system plus its own vision routines, some simple perspective and occlusion routines, and a model-builder--a program of complexity projected to be comparable to Fishman's.

We expect to do preprocessing (and perhaps some vision routines) on the PDP-15, and then transfer the resultant data via magnetic tape or a high-speed line to SUMEX or our CYBER for scene analysis. The space requirements for scene analysis on the second machine will be approximately twice those of the Fishman system (Figure 1). It is an experimental question how much low-level cone output must be used; and whether it may be beneficial to allow the scene analysis system to interrogate the 15.

While Fishman is developing his system, it will be valuable to use AI languages available on SUMEX-AIM to develop the overall architecture of the scene analysis system.

3. Our work on neural net systems has been conducted on an ad hoc basis both on the COINS PDP-15 (nerve nets for cerebellum; adaptation in visual cortex; stereopsis; etc.) and on the university's CDC-3600--now replaced by the CYBER system (e.g., learning nets in hippocampus and habituation studies). The CSN has now acquired a GT-44 interactive graphics system, and this is to be the core of an integrated brain-simulation system. The intended configuration uses the GT-44 for graphical manipulation and light pen interrupts, with the number-crunching to be done elsewhere. Each year, the CSN will welcome 4 Fellows to work on closing the gap between theory/computer studies and experiments in neuroscience. A SUMEX link would be of value in

experience for our Fellows, since they are distinguished biomedical people who otherwise might not come into contact with such large-scale AI techniques.

A. We are developing CORETEX*--a language for expressing neural nets in compact form. It is to handle systems with up to 50,000 synapses, and so will require compilation rather than interpretation. We are currently building a line to interface the RT/11 software of the GT-44 with the TEMPO front-end for time-sharing on CYBER. We shall start with 300 baud (which requires only an acoustic coupler); with a goal of 2400 baud (using 2 modems and a dedicated line) which is probably maximal for TEMPO.

A key research problem is to develop techniques for "smart" updating of display files to minimize the load on the communication link. We will use a modified "slide-box" technique, with much of this software resident in the GT-44. In other words, the current plans for CORETEX call for display management on the GT-44, and "number crunching" on the CYBER. During initial development, it appears unlikely that SUMEX-AIM has advantages over CYBER.

B. The initial stage of CORETEX development will <u>not</u> use AI techniques. However, the next stage--perhaps 2 to 3 years

*Not an acronym. Rather, the merging of "core" and "cortex" suggests computer modelling of brain.

away--will. Having developed a language and a library to facilitate the implementation of neural nets, we will then be able to turn to the development of AI-assisted interactive techniques to help an investigator search a space of neural net models to find those which meet both structural (anatomical) and functional (physiological) constraints. (Other relations of neural net work to AI are discussed in items 5 and 6 below.) For example, while the Kilmer - Olinski model of hippocampus requires only 300 instructions to program, the real research effort went into developing the proper connectivity embodied in this program. Thousands of instructions were generated in preliminary network configurations. Interactive, systematic, techniques are urgently needed to assist this model-building process, and the techniques of model-building established in the scene analysis project will provide powerful input here.

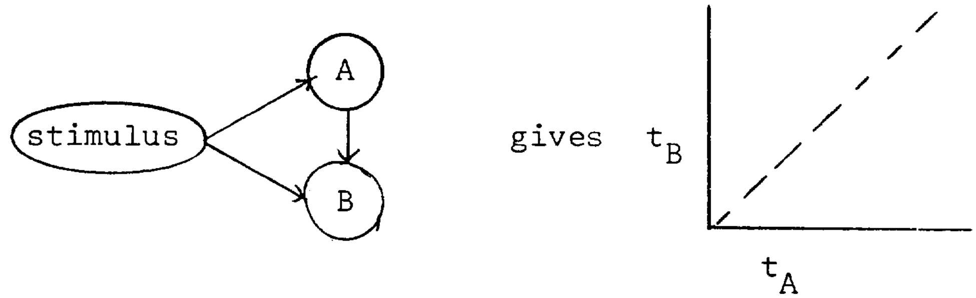
While the full space of neural net models is too large, it would be useful to have a system familiar with the ever-increasing body of existing neural models, and capable of retrieving the best for a given desired behavior. The common representation provided by CORETEX could act as a lingua franca for the construction of a computerized neural-model data base.

4. Spinelli conducts neurophysiological experiments on the function and development of the visual system in cats, monkeys, etc., using a PDP-11 to apply stimuli and monitor microelectrode activity. Lenherr is working in Spinelli's lab, as well as developing models which will be implemented on the CORETEX system. Spinelli plans to revise OCCAM--his model of associative memory--about a year from now; and to augment it with his own biologically-confirmed hand-eye project. Thus while his current needs are met by the PDP-11 in his neurophysiological laboratory, much greater computational power will be needed within 2 years.

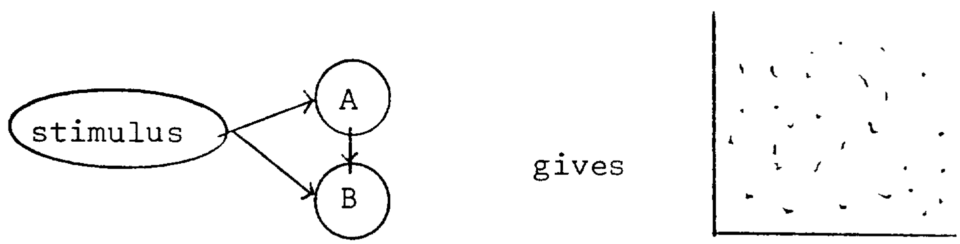
The short-range goal is to improve both on-line use of a minicomputer in the laboratory, and CORETEX independently, but the long-range goal is to link the lab minicomputer to an AI-augmented CORETEX system for on-line model building.

We have made a start in 2 studies: Lenherr has developed techniques to map visual RF's of cells by adaptive means. The stimuli were originally presented randomly, and responses monitored by the lab computer. As the computer developed an estimate ("internal model") of the RF, it biased the probability of stimuli in various regions so as to concentrate on patterns most likely to prove effective stimuli.

Karshmer has developed a program for investigating the connectivity of two simultaneously-recorded cells. By plotting the time of firing of cell A versus cell B (in response to a stimulus), various models of their interconnection can be studied, e.g.:




(i.e., constant delay)




(no correlation)

5. In modelling certain brain regions, detailed neural net simulation is possible; in other cases, simulation of gross functions of an array of cooperative subsystems (neuroheuristic programming) using data from lesion studies is the more realistic approach. If some regions are represented by neural net models, while others are given by neuroheuristic programs, the resultant configuration is an AI/neural hybrid. We are developing 2 such systems to relate neurophysiological, anatomical, lesion, and behavioral data: Arbib's study of eye movements in

visual perception (neural superior colliculus; AI cortex) and Kilmer's study of the role of hippocampus in animal behavior (neural hippocampus; AI cortex).

6. To facilitate both the development of parallelism in our AI scene-analysis system (2B, above) and to aid the construction of AI/neural hybrids, we are currently surveying AI languages to outline design characteristics for an AI language (tentatively called SAILOWAY since SAIL appears to be a useful first approximation--though the MICROPLANNER, CONNIVER, and QLISP facilities of INTERLISP will also prove useful) which will allow the full expression of parallelism appropriate to simultaneous activity of many brain regions, including provisions for calling of CORETEX macros. To actually build SAILOWAY would require new funding for systems programmers, as well as access to a large system on which SAIL is already available. However, irrespective of the level of implementation, our formalization of the essentials of AI languages should prove of general benefit to the AI community.

7. Surprisingly little AI research has focused on learning. We have two studies underway. Soloway is using baseball as a context for automatic inference of <u>rules</u>; Kilmer will use ethological descriptions of animal problem-solving as a context for automatic development of <u>procedures</u>. While the Meta-Dendral studies use a different microworld, both the philosophy and some of the techniques are similar to those in Soloway's system.

However, the Baseball microworld may prove more easily adaptable for other AI investigations. The general research area is that also inhabited by Schmidt's work at Rutgers on belief systems. It uses SUMEX. Schmidt is spending the year at UMass, and we are actively discussing common research strategies. If Soloway and Schmidt's work may be characterized as "mechanized theory formation" (which should thus feed back to our long-range goals [3B] for the development of the CORETEX system), then Kilmer's may be viewed as "mechanized procedure formation." Thus, while techniques in the first area may be applied to <u>diagnosis</u>; techniques in the second area should eventually aid the development of <u>therapeutic procedures</u>.

For both studies, LISP and SNOBOL appear inappropriate, while implementation on a system with either INTERLISP or SAIL is desirable. Unfortunately, the level of support for such AI languages on CYBER appears likely to be inadequate. For each of the Kilmer and Soloway projects, we estimate 20K of overnight storage on disc, with perhaps 2 hours of connect time per day--with a medium CPU load, since there will be more interaction than computation.

In the long term, these studies should feed back, via our AI/neural hybrid studies [5] to the studies of learning in neural nets conducted by Kilmer, Spinelli and Lenherr [3].

In conclusion, we are now working to get funding for a PDP-10 and full membership in the ARPA net. However, prior to such funding, SUMEX-AIM would be an invaluable support for a period of graceful transition.