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THEORY OF FUZZINESS AND ITS APPLICATIONS  
TO INFORMATION PROCESSING AND DECISION-MAKING

FINAL REPORT

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U. S. ARMY RESEARCH OFFICE

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This research concerns itself with the investigation of design goals of various approaches used in Artificial Intelligence (AI) programs in order to solve problems in various domains of knowledge. Research problems that were investigated in these AI problem-solving systems are 1) the representation of knowledge, 2) the complexity of a system's control structure, and 3) the error processing capabilities of a system.

Other issues of a system-design nature that are of interest in this paper include 1) system extendability, 2) expressability, 3) modularity, 4) readability, 5) explainability of behavior, and 6) domain appropriateness for the solution paradigm.

System extendability concerns itself with adding knowledge to a system in increments. Such a feature is necessary since large-scale systems must show competence on a subset of the domain knowledge. The knowledge can change over a period of time (as in medicine) and the system must allow adaptation to this new knowledge.

The expressability of a system depends upon the format can be either fixed (e.g., a conditional clause) or allow the knowledge encoder the full power of programming language for representation.

Modularity deals with the separation of a program into isolatable functional units. A highly modular system would allow changing a functional unit without necessitating changes to other units within the system.

Readability system concerns itself with 1) the ability of humans to understand a system's structuring of knowledge, and 2) the ability of a system to read portions of itself. The latter capability is necessary if the system is to do consistency checks of the knowledge encoded in the system.

Two extreme solution paradigms involve 1) procedural encoding of domain knowledge and 2) data-driven production-rule encoding. The structures of the various existing procedural systems actually range from a pure-procedural encoding of knowledge to a procedural implementation of production systems.

An advantage of production systems (i.e. collections of production rules plan data base) is their extendability. Since production rules are completely independent (they communicate only indirectly through the data base) the modification, addition, or deletion of any rule is not seen by any of the other rules. This modularity and the fixed format of rule representation (e.g. if hypotheses thru conclusions) aid machine readability. The fixed format requires a number of rules in order to represent control structures of more complexity than conditional statements. The basic system control structure is to 1) select a rule and 2) execute that the rule. A consequence is that at the beginning of any cycle potentially any rule can be executed depending only on the data base's current contents. The simple rule format allows easy human readability of individual rules but the behavior (on flow of control) of a system is normally very obscure. Production systems are most appropriate for domains where the knowledge is a collection of independent facts which are encodable as rules.

The various procedural systems involve problem-solving domains where there is interaction (e.g. competition or communication) between pieces of knowledge. In these systems the knowledge is encoded in procedures. Use of a piece of knowledge is equivalent to executing the associated procedure. Along with the increased expressability inherent in a procedure realizable control structures of immense complexity are

possible. Here the unit of modularity is the procedure: all relevant piece of knowledge are combined into a single procedure. This feature allows for easy readability of procedures by humans; but currently allows only limited machine readability of procedures. As such, the explanability of system behavior is dependent on the systems; complexity of control flow and possible parallel executing of procedures. Only those procedural systems that use pattern-directed invocation of procedures enjoy extendability; otherwise, reprogramming is necessary.

Both approaches to system design (production systems on procedures) have equivalent computational power. Their appropriateness in future systems will be dependent upon the desired features of a system's design; Hybrid system's are beginning to appear.

#### Personnel

Mr. Ralph Sobek has been advanced to Candidacy. Ph.D. expected in 1977.

#### Publication

Technical report is in preparation.