Artificial Intelligence at Schlumberger

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SCHLUMBERGER is a large, multinational corporation concerned primarily with the measurement, collection, and interpretation of data. For the past fifty years, most of its activities have been related to hydrocarbon exploration. The efficient location and production of hydrocarbons from an underground formation requires a great deal of knowledge about the formation, ranging in scale from the size and shape of the rock's pore spaces to the size and shape of the entire reservoir. Schlumberger provides its clients with two types of information: measurements, called logs, of the petrophysical properties of the rock around the borehole, such as its electrical, acoustical, and radioactive characteristics; and interpretations of these logs in terms of geophysical properties, such as porosity and mineral composition.

Since log interpretation is an expert skill, the emergence of expert systems technology prompted Schlumberger's initial interest in Artificial Intelligence. Our first full-scale attempt at a commercial-quality expert system was the Dipmeter Advisor (Davis 1981; Gershman 1982; Smith 1983a). This system attempts to emulate human expert performance in the interpretation of subsurface geological features from measurements of the tilt of the underground layers. The program is written in INTERLISP-D and operates on the Xerox 1100 series Scientific Information Processor. It includes approximately 90 production rules, a forward-chaining inference engine, several feature detection algorithms, and a menu-driven graphical user interface. The Dipmeter Advisor system has recently begun to see service in some of Schlumberger's Field Computation Centers.

Following these initial efforts, Schlumberger has expanded its Artificial Intelligence activities, and is now engaged in both basic and applied research in a wide variety of areas:

Schlumberger-Doll Research is the primary research center for Schlumberger's wireline activities. AI activities are also being pursued at other Schlumberger locations, often jointly with SDR The locations related to logging and interpretation include: Schlumberger-Doll Research, Ridgefield, Connecticut *(Contact: Peter Will)*; Schlumberger Well Services, Austin, Texas *(Contact: Scott Guthery)*; Schlumberger Well Services, Houston, Texas *(Contact: Scott Marks)*; Nippon Schlumberger, K K , Tokyo, Japan *(Contact: Dennis O'Neill)*; Étude et Production Schlumberger, Clamart, France *(Contact: Bob Langley)*. Other Schlumberger companies involved in AI research include: Fairchild Research Center, Mountain View, California *(Contact: J. M. Tenenbaum)*; GIERS, Montrouge, France *(Contact: G Gibbons)*

Expert Systems

Current work in expert systems is concerned with developing techniques for building more robust and versatile log interpretation systems. One shortcoming of "first generation" expert systems, such as the Dipmeter Advisor, is their inability to reason about the task that they attempt to perform. Any description of the overall task is usually procedurally encoded and unavailable for examination. Recent work has focussed on developing a hierarchical representation for interpretation tasks in terms of modules connected with control and data flow links. The representation provides a descriptive wrapper for existing quantitative interpretation systems (often large FORTRAN programs) so that they can be integrated with expert interpretation systems. The explicit data descriptions have also helped to increase the uniformity of the user interface to the combined system. Another weakness of first-generation systems relates to robustness. To address this issue, we are examining machine learning based on rule justification and a variety of representations of geological and signal processing knowledge. We are encoding the support for a small segment of the rules from the Dipmeter Advisor system—the assumptions and approximations made, and the underlying geological models upon which they depend. We are also attempting to find domain-independent mechanisms that can use such information to generate plausible explanations of the failures that could have occurred in chains of reasoning.

Participants: Reid Smith (contact), Paul Gingrich, Gilles Lafue, Howard Winston, Robert Young.

Knowledge Representation

Over the past two years we have developed a knowledge representation system, called STROBE, that provides structured object support tools for INTERLISP programmers (Smith 1983b, 1984). It supports multiple knowledge bases, tangled generalization hierarchies, flexible inheritance of properties, event-sensitive procedure invocation, and communication among separate knowledge bases (both on the same host and between hosts connected via Ethernet). This system forms the representation substrate upon which we base much of the research and system development currently underway at Schlumberger. An interactive knowledge base ed-

itor called IMPULSE has also been developed for STROBE (Schoen 1983). It offers a relatively transparent interface to knowledge bases. This transparency helps to ease the problem of communication between domain expert and computer scientist about the knowledge that is under study.

Participant: Reid Smith (contact).

Natural Deduction

Research is currently being conducted in the use of natural deduction as a framework for reasoning about problem solving. An interactive workbench for the construction of natural deduction proofs, called COGITO, is under development (Smoliar 1983). Our approach to natural deduction follows that of the text, "Logic: Techniques of Formal Reasoning," by D. Kalish, R. Montague, and G. Mar. Under COGITO, proofs may be developed step-by-step using a menu-driven protocol, they may arise through the evaluation of "proof expressions," or such expressions may be synthesized by "tactics" applied to "goals." COGITO is implemented using STROBE. The object-oriented approach contributes to COGITO's ability to maintain multiple "views" of a proof. It also allows for a convenient interface between knowledge related to a given problem domain and knowledge concerned with mechanisms for reasoning which may be applied to that domain.

Participants: Stephen Smoliar (contact), Paul Baker.

Knowledge-based Signal Processing

Knowledge-based techniques have the potential for significantly augmenting numeric signal processing algorithms. Our initial experiments involve using knowledge of tool responses in specific lithologies in combination with the Fairchild "scale-space filtering" algorithm. The knowledge-based processing transforms the signals into qualitative descriptions which are intended to support future work in automatic demarcation and identification of the vertical sequences in the rock formations downhole. This activity is tightly coupled with the work in knowledge representation and natural deduction, which will provide insights on how to analyze the results of the knowledge-based signal processing.

Participant: Brij Masand (contact).

Learning

Machine learning is currently being investigated with respect to the acquisition of techniques of quantitative log interpretation. Our initial studies have attempted to develop a formal characterization of what it means for a machine to learn about log interpretation and to define a suitable trial exercise which can demonstrate manifestations of such a learning activity. The exercise involved an example of learning by debugging. A scenario was designed concerning the use of a class of measurements to determine certain petrophysical parameters. As part of this scenario, a "bug" is discovered when two such calculations of the same parameter are found to be in disagreement. The activity of debugging reveals an assumption which affects only one of the two calculations and the need to reassess that assumption.

Participant: Stephen Smoliar (contact).

Automatic Programming

The automatic programming project has two long-term goals: to develop detailed models of the programming process; and to build automatic programming systems for use in real-world situations. We are pursuing these goals in the context of two application domains. For the first, quantitative log interpretation, the key issue seems to be the interaction between several diverse types of knowledge, including knowledge of log interpretation, formal mathematics, programming techniques, and the target language and architecture. To date, we have outlined a model of programming which characterizes the interaction of these types of knowledge within a transformational paradigm.

ϕ_{nix} is an experimental system being developed to refine and validate the model (Barstow 1984; Barth, Barstow, Passera 1984). For the second domain, data acquisition software used during logging, the key issue involves programming techniques for handling real-time situations with feedback loops. Despite the dissimilarities of the programming tasks, we expect to use knowledge representation techniques similar to those of the ϕ_{nix} project.

Participants: David Barstow (contact), Paul Barth, Paul Dietz, Richard Dinitz, Sol Greenspan.

Distributed Systems

Our work in distributed systems has involved blending local area network technology, high performance LISP workstations and knowledge representation to provide an integrated problem-solving environment. The interpretation of oilfield log data involves human reasoning aided by processing on a variety of computing engines, using data derived from downhole measurements, local geological knowledge, and regional experience. Interpretation systems presently in the field make limited use of the parallel processing capabilities afforded by passive networks and specialized processors such as array processors, symbolic computers, and graphics engines. At Schlumberger-Doll Research we have installed a variety of networks over the past three years (3MB, 10MB Ethernet, DECNET), communicating with Xerox Dolphins, Dorados, and Dandelions and augmented by a number of special purpose devices such as FPS Array Processors and high resolution color display devices. Much of the work to date has been in making the power of these devices easily available to the non-computer oriented interpreter. More recently we have extended the capability of the STROBE knowledge representation system to allow knowledge bases on separate nodes to communicate in a transparent fashion through the use of messages. Future research using these available tools and systems will be to examine the adequacy of the local area network architecture for acquiring and processing data from sources operating with significant real-time constraints.

Participants: Peter Will (contact), Reid Smith.

Databases

Our interest in AI and databases is related to the need of expert systems for database access. The fields have had

several points of contact: they both rely on data/knowledge representation models and they both involve some inference making. However, they have evolved separately from each other, each placing its emphasis on different aspects. It is currently difficult to integrate existing expert systems with existing Database Management Systems. We are currently extending STROBE to address some of these difficulties (Lafue 1983). Of particular interest is the automatic management of semantic integrity, especially regarding the cost of generalized integrity checking.

Participant: Gilles Lafue (contact), Patricia Carando.

Graphical Modeling

The goal of this program is the reconstruction of 3D geometrical models representing the earth's crust in an oil reservoir. The inputs to the model are a wide range of measurements of physical properties which vary greatly in scale: seismic data allows the identification of large scale formation and faults; well log data gives properties of the smaller bedding layers in the vicinity of a well; and rock samples allow the determination of the microscopic features of the rock pore space. The objective is to integrate the different types of data into a single consistent model which contains both static and procedural attributes. The resulting reservoir model would be used as an aid in the interpretation of data from new wells in the reservoir, as well as for the planning of the oil production from the reservoir. The program uses an Adage/Ikonas graphics system for 3D image synthesis and interaction, STROBE for the representation of the knowledge base, and D-machines for the underlying geometric reasoning.

Participants: Peter Will (contact), Ingrid Carlbom, Indranil Chakravarty.

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