an unrestricted language processor. Command restricted interfaces should be used on future menu-based programs.

PSYCHOLOGICAL THEORIES

Theoretically, the reason that the command restricted language processor was easier to use is because it has fewer commands. The subject has a feeling of anxiety when they are confronted with many commands in the case of an unrestricted environment. They get confused at the many commands. They feel "unorganized." With the command restricted language processor they don't feel anxious because the few commands don't make them feel unorganized. They can even be in the psychological condition called flow when they are interacting with the command restricted language processor.

AUTOMATED HEURISTIC ANALYSIS OF SPECTROSCOPIC DATA

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INTRODUCTION

Spectroscopic data consists of a set of numbers which may be plotted on a graph. These numbers indicate a range of values rather than a single discrete value. It is straightforward to assign a meaning to a single value, but interpreting the meaning of a range of values requires more judgement. In nuclear physics, spectroscopic data is related to the mass or energy of a particle detected from a nuclear reaction. these data are discrete numbers, but because of the interactions between the nuclear reaction and the particle detector, a range of data is collected. Although it takes many years of experience to learn how to interpret nuclear physics spectra, the data reduciton and analysis are fairly routine. The routine parts of data reduction and analysis can be automated by expert system techniques.

Expert system techniques have opened a new arena for problem solving. Project feasibility using expert system heuristics has been demonstrated in several areas, such as medical diagnosis, numeric analysis, and spectral interpretation (Ganascia, 1986; Kowalik, 1986; Shortliffe, 1976; Simon, 1988; Van Melle, 1980). Both heuristic methods and algorithmic methods are useful techniques for problem solving. The synthesis of numeric and heuristic techniques has proven to be useful in data reduction and analysis. In this research, the goal was to develop an automated spectroscopic data reduction and analysis program for use in nuclear physics. This paper presents an overview from the expert system perspective of the BINIT expert system project which automated the reduction and analysis of nuclear physics spectroscopic data. In this work, the name BINIT expert system is an approximate term used to indicate the algorithmic program BINIT, which has been extended and improved by incorporating heuristic knowledge in the code, as opposed to the classic expert system which has rules separate from code.

BINIT

Many sciences, such as physics, chemistry, and engineering, use statistical data to represent and analyze typical situations within the field. Some of the methods used to manipulate these data include statistical clustering, Monte Carlo modeling, and graphical analysis. In this paper we discuss the BINIT system which uses graphical analysis. The details of the algorithms used in BINIT are described in Chulick, et al. (1973) and Simon (1983).

Running BINIT for reduction and analysis of the data takes five general steps. First, the energies of all data and all particles are graphed, errors are discarded, and axes for the graphs are calibrated and normalized. Second, these graphs may be rerun to verify the calibrations. Third, graphs of the energy differences are plotted to resolve the different particle masses. Fourth, windows or bins (BIN-IT) are put on each mass. Fifth, the data for specific, binned particles are collected in individual graphs of the energy for each particle.

These five steps are repeated for each angle. Because of the large amount of data (> 1 million), the number of different types of particles involved (>10), and the number of angles used (>5), reduction, calibration, and analysis took as long as three months using BINIT. This meant three months passed before interpretation of the results could begin.

From the repetitive nature of the steps, the tedious human effort, and the mechanical numeric method used, it seemed clear that this task could be automated using expert system techniques.

BINIT EXPERT SYSTEM

Expert systems are more often cited as good for symbolic and qualitative analysis than for quantitative analysis. However, expert systems have been used to interpret large amounts of data (Bender, et al; 1985, Kowalik; 1986, Simon; 1987). An expert system can tirelessly reduce and analyze large amounts of data. The expert system can distribute the knowledge and advice of the expert to various locations. This distribution has two benefits: 1) more people can use the expert's knowledge and advice; and 2) the human expert is free to work on new, less routine work. In this case, the author was freed to synthesize possible reaction mechanisms, rather than spend time reducing the data.

A number of specific nuclear physics calculations were used to implement the heuristics (Simon, et al.; 1984) described below. For clarity, the flow of the modified program is described in general terms.

The first version of the BINIT expert system performed the calibration automatically. The second step for verification was skipped. The data was rerun without interruption and the location for beryllium-8 was determined by the comparative paucity of data. This span of distance was used as the measure of one unit of mass. This distance was used to set the windows. These windows were plotted and examined. The windows appeared to be somewhat off, so the windows were reset by hand, and the energy spectra were plotted. This BINIT expert system approach reduced total analysis time from three months to less than two weeks. The bottleneck in this cycle was the manual resetting of the windows. Through detailed Gaussian analysis, empirical experimentation and rerunning, the author determined a difference of 5% (not necessarily an improvement) between the automated heuristic and the manual resetting of windows. Definitely within allowable tolerances.

With that anxiety under control, the author allowed the BINIT expert system to process a complete set of data. With no intervention, the BINIT expert system completed the normally three month process in less than a weekend, 37 hours.

Because no human intervention was needed, steps 1-3 were combined and steps 4-5 were combined for a total of two passes. The majority of time now shifted from manual data reduction and analysis to data input and output, and graphing production. Because of the mass of data involved (> million points) and system limits, processing time could not be further reduced. Clearly there was no reason to be overambitious or greedy; the results were more than satisfactory.

After the BINIT expert system finished processing the data, graphs were generated from the data so that the author could interpret the results and determine the mechanism of the original nuclear reaction.

KNOWLEDGE REPRESENTATION

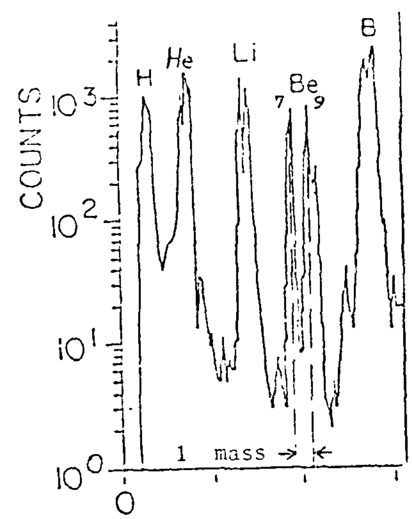
The Binit expert system used heuristics to represent and apply the knowledge of the nuclear physicist. Heuristics are general rule-of-thumb guidlines for quickly choosing the correct action to take. An important heuristic was that the graphic distance covered by one mass did not vary appreciably from one particle to another.

Some additional, more specific heuristics include:

1. Hydrogen has three common masses: 1, 2, 3.
2. Helium has two common masses: 3, 4.
3. Lithium has two common masses: 6, 7.
4. Beryllium has two common masses: 7, 9.
5. The distance between beryllium-7 and beryllium-9 is equal to the distance covered by one mass. This is because beryllium-8 does not show up.

These are not guaranteed rules, but general heuristics that usually worked. In fact, before being incorporated into the BINIT expert system, these heuristics were adequate to allow a high school senior to perform the mechanics of data reduction with only occasional supervision to handle the exceptional conditions.

SPECTROSCOPIC EXAMPLE



In this example graph, we see the number of data points for each elemental mass. In this graph, the standard chemical element abbreviations are used. The distance of one mass unit is indicated between beryllium-7 and beryllium-9.

SUMMARY

This paper has shown one way to incorporate the techniques of a heuristic expert system into a data analysis routine to improve overall performance of data reduction and analysis. Also, these techniques were implemented in a conventional programming language such as FORTRAN, although actually developing the techniques might have been more efficient in LISP. Addition of expert system techniques to numeric analysis routines promises to be a fruitful marriage of expert systems and conventional programming.

EPILOGUE

A totally new set of procedures based on similar heuristics has replaced the BINIT expert system. Work has continued so that these heuristics might eventually be incorporated at the data acquisition stage.

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Manhattanville College Expert Academic Advisor-Preliminary report

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ABSTRACT

In this paper I summarize the experiences of four novice knowledge engineers in the development of an expert academic advising system. We discuss the ideas and techniques behind the system and some of the methods developed and used in implementing the system using a frame-based expert systems shell.