

Automation

INTERPRETIVE PROCESSING/EXPERT SYSTEMS: AN INITIATIVE IN WEATHER DATA ANALYSIS AND FORECASTING

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ABSTRACT

Interpretive processing is a computer interactive procedure that enhances the abilities of the weather forecaster to decide on a forecast. The procedure makes it easier to draw conclusions from the meteorological analysis of observational data, forecasting techniques, and past forecast experience available when deciding on a forecast. This article provides some concepts for the application of Artificial Intelligence (AI)/expert systems technology to interpretive processing. Expert/knowledge-based systems exhibit a three-fold benefit for weather forecasting. They are: (1) providing improved data analysis and decision-making support due to enhanced consistency and thoroughness; (2) supporting training of new forecasters; (3) supporting skill maintenance for experienced forecasters, especially with regard to their action in infrequently occurring/unfamiliar situations.

The use of expert systems would help ensure that the best forecast knowledge is available to the forecaster on duty. The AI/expert systems concepts would be applied as part of the effort toward further automation in NWS field operations and, within the scope of interpretive processing, to implement a forecasting system management aid and empirical procedure found useful in deciding on a forecast.

1. INTRODUCTION

A Department of Commerce goal is the restructuring of the National Weather Service by 1990 to provide more timely and accurate forecasts with improved cost-effectiveness. In keeping with this goal, the NWS is working on further developments in the automation of field operations. Related to this, the agency has initiated an effort in Interpretive Processing. Interpretive processing is defined as a computer interactive procedure that enhances the abilities of the weather forecaster to decide on a forecast. The procedure makes it easier to draw conclusions from the meteorological analysis of observational data, forecasting techniques, and past forecaster experience available when deciding on a forecast.

This report provides some concepts for the application of Artificial Intelligence (AI)/expert systems technology to Interpretive Processing, especially with respect to the possibility of enhancing the contribution of forecaster past experience. The thrust of this initiative would be two-fold: (a) to formalize the capture of empirical knowledge/procedures used by field personnel and, (b) to develop an information management support system, a "weather information processing executive." This executive would orchestrate the interaction and use of various prediction models and national guidance, would provide for an increased degree of automation of the surveillance (met watch function) and provide "guidance" to the forecaster with respect to things that he should do, such as to issue watches and warnings.

The possible value of Interpretive Processing in the next generation of automation in NWS field operations is suggested by the following observations about CSIS (Centralized Storm Information System) : (3)

"Having a computer to help organize the forecaster's work, remind him of the status of his forecast products, and keep him up to date in a rapidly changing weather situation has proven invaluable in dealing with wide spread severe storm outbreaks."

Seemingly, this statement could apply to other weather forecasting environments as well.

The Interpretive Processing (and AI/expert systems) thrust is in recognition of the need in the next few years to support the assimilation of the significantly greater amounts of data that will be required for higher resolution (mesoscale forecasting). This is the principal attribute of the next generation of automation for the NWS field offices.

"Artificial Intelligence" may be defined as "A subfield of computer science concerned with the concepts and methods of symbolic inference by a computer and the symbolic representation of the knowledge to be used in making inferences. A computer can be made to behave in ways that humans recognize as 'intelligent' behavior in each other."(4) Perhaps more usefully, AI can be defined in terms of its applications to the more specific engineering goal of "...the development of computer programs that can solve problems normally thought to require human intelligence."(5)

"Expert systems" can be defined as "...problem-solving computer programs that can reach a level of performance comparable to that of a human expert in some specialized problem domain."(6) Often, the term "knowledge based system" is employed as more or less the equivalent of "expert system". Perhaps, as suggested in reference 5, a differentiation can be made between the two, to wit:

"...a knowledge-based system is an AI program whose performance depends more on the explicit presence of a large body of knowledge than on the possession of ingenious computational procedures; by expert system we mean a knowledge-based system whose performance is intended to rival that of human experts."

Some of the basic concepts of expert systems have already been applied in weather forecasting, especially of severe weather by the National Weather Service and Air Weather Service, U.S. Air Force (7,8,9,10). These applications were not formally "expert" or "knowledge-based" systems, but they did

address the important objective of capturing the experience and judgement of senior forecasters for use by those with less experience. They also served another objective, to help to fuse the knowledge and experience of several experts. The fusion process is a difficult one. It is similar to the forecaster's obtaining the consensus of his peers about his weather hypothesis before formalizing it into a forecast. Recently, as part of the initial NWS development activity on Interpretive Processing systems, an experimental algorithm (11,12) that exhibits learning behavior has been devised to predict the "likelihood" or "possibility" that a severe thunderstorm will occur. The algorithm has been programmed in the BASIC language, suitable for use on a personal computer.

The development of AI/expert systems algorithms for weather information processing and forecast generation support will have the potential to enhance the basic meteorological science itself by forcing codification of relevant procedures, thought processes, etc. in a precise, thorough, and consistent manner. Also, when available on-line to the forecasting community, such algorithms should enhance the skills of the forecaster through the process Cook has termed "interactive judgment" (1). He defines it as "...a procedure for helping decision makers to understand the basis of their judgments and to improve the quality of their decisions...". That is, the forecaster may learn from the algorithm (provided it exhibits a sufficient capability to "explain" its "line of reasoning" or provide a "trace") and the algorithm can be modified, based on inputs from the forecaster or, possibly, by monitoring his actions. This concept epitomizes a computer interactive system.

It appears that expert/knowledge-based systems exhibit considerable potential benefit for weather forecasting. The benefit should be three-fold:

- (1) to provide improved data analysis and decision-making support due to enhanced consistency and thoroughness;
- (2) to support training of new forecasters;
- (3) to support skill maintenance for experienced forecasters, especially with regard to their actions in infrequently occurring/unfamiliar situations.

The use of expert systems would help ensure that the best forecast knowledge is available to the forecaster on duty. This knowledge would be derived from "experts" in the appropriate forecasting areas. The

knowledge incorporated into the system would be the result of fusing the inputs from the set of "experts." The acquisition of such a knowledge base including its systematization (to assure internal consistencies, etc.) is perhaps the most difficult aspect of constructing an expert system; also, it is the most expensive.

Weather forecasting may be considered as a decision-making task. Information processing methodologies being developed for medical diagnosis, such as expert systems and AI, hold promise for application to the problem of weather forecasting. Indeed, Allen has noted that "A number of similarities between weather forecasting and medical diagnosis become evident when each is considered as a decision task." He also has observed that "...in both tasks the decision maker is faced with information of varying degrees of significance...both tasks involve a selective gathering of data from prodigious data sources". (14) Weather forecasting also exhibits structural similarities to military tactical command, control, and communications (C³) systems. C³ systems must handle an ever increasing volume of data provided by new sensors. Like the weather forecaster, the C³ system user is in a situation in which "...this new sensing capability must be matched by an ability to filter, discriminate, correlate, and fuse the information...(presented to him)". (15)

In both cases, the problem is one of information reduction. We construct new types of systematic procedures to make conclusions and support decision-making, based on observed data, but without requiring the "bandwidth" of the human information channel to increase corresponding to the amount of new information available. Thus, a major objective of the NWS's effort in Interpretive Processing is to provide an "executive function" or "information management support system." It would provide process management assistance to the forecaster to orchestrate the interaction and use of numerical models, guidance, and AI/expert/heuristic/knowledge-based systems. It would also provide aid to the forecaster in sequencing his activities such as issuing watches and warnings, etc.

As part of its program to realize the Commerce Department goal of more timely and accurate weather forecasts, the Weather Service recognizes the need in the next few years to support the assimilation of the significantly greater amount of data that will be required for higher resolution (mesoscale) forecasting. This greater amount of data will have to be processed without any significant increase in manpower. This means that an increase in productivity is inherently an objective of

the Interpretive Processing initiative. Further, the goal of enhanced forecasting accuracy is commensurate with the goal of achieving a higher quality of forecasts. The goals of higher productivity in the forecast development process and higher quality in the resultant forecast products should be achievable in the next-generation NWS field automation effort through the use of Interpretive Processing techniques.

2. CONCISE SUMMARY OF EXPERT/KNOWLEDGE-BASED SYSTEMS

This section briefly summarizes the principal features and some desirable capabilities of knowledge-based systems and outlines their potential usefulness to the National Weather Service.

An expert/knowledge-based system captures the problem solving expertise of a field of endeavor (or more customarily, a well-bounded portion thereof) and uses it as a computer-based consultant that can provide intelligent assistance to a practitioner in that field. The basis for such a system is obtaining knowledge from an "expert", in recognition that an expert's high level of performance is due to: special knowledge, judgment, and experience. "Knowledge" is to be distinguished from "information"; "knowledge" is information that has been processed, reduced, and otherwise has been gleaned of the elements that are significant for the task at hand. As Feigenbaum and McCorduck (ref. 4, p. 75) have noted:

"The power of the expert systems comes from the knowledge they contain. That knowledge is, at present, stored in the heads of human experts, and getting it out - what AI researchers call the knowledge acquisition problem - is the biggest bottleneck that the knowledge engineers currently face."

Obtaining "knowledge" to build into an expert system is difficult for at least two significant reasons: (1) often a person is not cognizant of the thought processes - or the chains of reasoning that he employs to reach a conclusion; (2) often there is not one specialist whose expertise either spans the entire problem of interest or with whom other acknowledged experts agree exactly as to the nature of the parameters describing the process of concern.

An expert system has three principal structural components (see Figure 1) (4): an input/output system, an inference system, and a knowledge base. The knowledge base contains "facts", such as from a textbook, and "heuristic knowledge", which is the knowledge of good practice or of making a good guess. The inference subsystem, often constructed with "IF-THEN" rules, draws

