THE PAR1 DSS
AND ITS APPLICATION TO EXTENSION

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Introduction

Of the many issues concerning the agricultural industry today, soil degradation is one of the key points which needs attention. Conservation production systems must be implemented to ensure the long-term sustainability of the soil resource and in turn the sustainability of agriculture. Conventional farming practices are complicated, but conservation farming practices are very complex, with more prevalent concerns, including crop rotations, herbicide residues, increased susceptibility of plant diseases, and especially residue management, as a result of minimum tillage. Producers need sound advice and accurate information on all aspects of their farm operations in order to make appropriate conservation farming decisions while also maintaining the economic viability of their operations. In order to deal with the many complex issues of conservation farming and numerous alternatives available, farm managers need access to available information as well as access to multiple experts.

A vast amount of technical information, both published and unpublished, resides in various locations which is not readily available nor utilized at present. In addition, many "experts" in various disciplines at research centres, educational institutions, government extension agencies, farms, and private sector businesses, have considerable knowledge and experience that are not being fully utilized. Innovative and enhanced methods and techniques are required to make this information and knowledge available to farm managers to support their production decisions.

Agriculture and Agri-Food Canada, Research Branch, under the Parkland Agriculture Research Initiative (PARI), is developing a conservation production decision support system, comprising multiple expert systems (i.e. agents) to facilitate on-farm decision making focusing on encouraging adoption of economically viable soil conservation practices. The primary clients of the PARI Decision Support System (DSS) are innovative farm managers interested in adopting conservation farming practices, as well as producers who are already engaged in conservation farming practices. Other clients include extension specialists, research scientists, and private industry.

Expert Systems and Decision Support Systems

An Expert System is a computer program that solves complicated problems that would otherwise require extensive human expertise. It does this by simulating the human reasoning process by applying specific knowledge and inferences[1]. Expert systems are a branch of artificial intelligence, which is a science that attempts to develop thought tools by programming computers to mimic the kinds of human behavior that require intelligence, make judgments and consider experiences.

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1 that which is inferred, a deduction or conclusion

A decision support system combines information, knowledge, and human expertise, by integrating expert systems, simulation models, and any other combination of software and/or information which can aid the management decision-making process through interaction with the user. The PAR1 DSS will provide producers with effective decision support for adopting and maintaining conservation farming technologies. For example, the PAR1 DSS will assist the producer in diagnosing soil erosion, economically analyze the producer's farm and indicate the level of risk in adopting conservation farming practices. The PAR1 DSS will support the conservation farmer's crop production by advising on crop rotation, variety selection, fertility, weed identification and severity, pest control, and machinery selection or modification for managing residue.

Benefits of Decision Support Systems

A decision support system can provide unbiased accurate and meaningful decision support from the "informational" level to the "expert" level, that is specific to the farm manager's operation, given sufficient on-farm data is available. At the low level of decision support, the growing acceptance of the Internet is providing for the delivery of timely information, including newsletters, informational bulletins and answers to frequently asked questions, creating a delivery mechanism for generalized decision support. At the high level, decision support systems can utilize incomplete and uncertain data, experimental knowledge, and incorporate multiple knowledge sources (i.e. expert systems) into one comprehensive knowledge system. Not only can decision support systems provide pertinent and specific decision-making support, but also supply detailed explanations of reasoning procedures to rationalize the recommendations specified.

The PAR1 DSS Infrastructure

The PARI DSS is being collaboratively developed by Agriculture and Agri-Food Canada's Research Branch with several partners, including producers, provincial governments, universities, and private industry. Producers are involved in supplying ideas on the design, content and operation of the PARI DSS. With the PARI DSS being collaboratively developed, a framework, illustrated in Figure 1, has been designed for its development which permits finished modules to be used on their own while providing natural growth for the overall DSS. This framework provides a "single window" to conservation decision support by providing 3 different levels of expertise. Level-1 consists of basic decision support, based on information, databases and directories contained within Internet Web pages. Level-2 provides advanced decision support consisting of standalone expert systems. As illustrated in Figure 1, Level-3 provides the most advanced decision support by combining expert systems (i.e. agents), with the aid of a blackboard system, which cooperate together to provide a high level of integrated decision support. This is similar to a problem-solving team of different human experts, functioning in a controlled and cooperative environment, using a wall blackboard. The controlling and cooperation is managed by a Global Control Knowledge Base, similar to a team-leader who chairs (i.e. controls) a problem-solving team of human experts.

Our goal of an "open system", not only enables the use of existing "off-the-shelf' agents (i.e. expert systems), but provides collaborators the freedom to develop expert systems for their own specific use. Furthermore, integrating heterogeneous reusable agents provides a natural and flexible development methodology whereby new agents can be added and existing agents deleted in response to changing system requirements. Additional advantages of using "off-the-shelf' heterogeneous reusable agents, which fulfill our goals, include [Lander, 1994]:

2 possibly a classroom or a conference room

- the uniformity of expertise within each agent make them easier to design, develop and maintain than single large systems;
- consistency of knowledge can be maintained within local boundaries without necessitating agreement across boundaries;
- software modifications can be focused at the problem or enhancement within the agent, without requiring changes to be disseminated throughout the entire system.

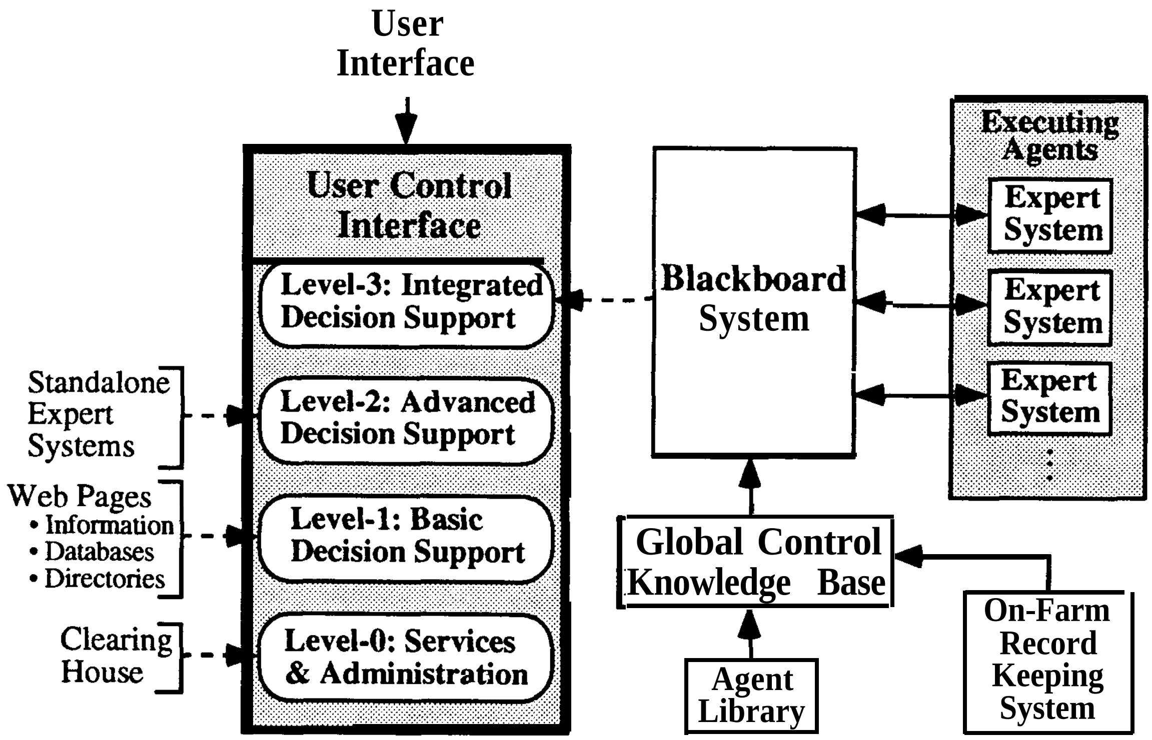

Figure 1 :PARI DSS Infrastructure

Collectively joining diverse knowledge from the viewpoints of cooperating experts provides an extremely important source of balance and robustness in many real-world situations contributing to comprehensive credible solutions. This is characterized by carefully selected human project teams and work groups. Teams and groups can solve problems which are normally beyond the comprehensiveness of individual experts, and in doing so, provide potentially creative and innovative solutions resulting from a rich and varied body of knowledge [Lander and Lesser 1989].

Cooperating Expert Systems

When human experts cooperate on a single problem, they contribute their multiple diverse viewpoints during the problem-solving process. For instance, a plant breeder and an agrologist work together to develop crops with high quality and good yields. Similarly, a chemist and a machinery engineer cooperate to produce effective and environmentally safe methods of applying herbicides. In general, the greater the complexity of problem-solving, the more cooperating experts needed. Cooperation and diversity can be advantageous, providing increased problem-solving capabilities beyond the individual expert and promoting creativity and innovation [Lander and Lesser 1989]., However, conflicts result from cooperation which must be resolved among the experts through information exchange.

In the paradigm of cooperating expert systems, heterogeneous reusable agents must be integrated to provide effective technical interaction. Within these systems, the state of problem-solving must be communicated and agents' actions must be coordinated to arrive at mutually acceptable solutions. However, in these cooperative environments, just like with human experts, conflicts must be resolved as a result of incomplete or inconsistent knowledge and/or incorrect assumptions, different problem-solving techniques, and different solution evaluation criteria [Lander and Lesser, 1994]. Anticipating and removing potential conflicts through software engineering at agent-development time is not possible since it is not known what knowledge will be contained in an open system. Software reuse in any form is hindered by the absence of technical tools and techniques to support information sharing [Neches et al., 1991].

The PARI DSS is being developed collaboratively with cooperation of specialists from federal and provincial governments, universities and private industry. All of the expert systems within the PARI DSS either exist "on-the-shelf' as reusable agents or are being developed as reusable agents. A specialized multi-agent system which shares expertise has several advantages over a large monolithic system developed to solve the same problem(s) [Lander and Lesser, 1989]. The multi-agent system approach provides the PARI DSS with a natural, flexible development framework in which to integrate heterogeneous reusable agents, as well as the capability to implement agents independently with minimal time and resource requirements. Agents developed for multiple uses are generally more reliable and their development cost can be amortized over many uses [Lander and Lesser, 1994]. In addition, a modular expert system approach provides the ease and simplicity associated with developing, debugging, testing and maintaining small systems.

Record Keeping for Decision Support Systems

Normally, a farm manager will seek out and validate, in their own mind, what sources of information and knowledge are credible. These sources of credible information and knowledge might be, for example, persons, publications and/or the media. Whoever and/or whatever these sources are, the farm manager analyses them as being able to provide a certain level of knowledge or information within a specific domain as it pertains to their own farm. For a decision support system to obtain a high rating of credibility from the farm manager, its support and services must be accurate, convincing[3] and most importantly the decision support provided must be targeted to the specific farm manager's enterprise.

In order for an agricultural decision support system to accomplish this, on-farm databases must contain accurate and complete data. Hence, the most important requirement in developing a credible agricultural decision support system is implementing a sound record keeping system for collecting, validating, storing, retrieving and updating complete sets of on-farm data. Never has the old, but accurate, phrase "garbage in - garbage out" been more applicable. It will make little difference how "expert" the internal expert systems ate or how "knowledgeable" the knowledge bases are, if the data driving these internal components are not accurate, complete and relevant to the specific farm enterprise. Without a sound on-farm record keeping system, the agricultural decision support system will not be able to provide the required support, and will fail the farm manager's credibility test.

3 be able to substantiate why it is making a particular recommendation

A successful decision support system must gain the confidence of the user. One of the downfalls of decision support systems, which has led to poor acceptance, is the inability of the decision support system to adequately explain and justify its recommendations based on the farm manager's on-farm data and information. To be credible, a decision support system must be able to customize its recommendations so that the farm manager can easily understand them and apply them to their particular farm enterprise regardless of the farm manager's knowledge, education or level of understanding [J.E. Greer, Falk K.J. Greer and Bentham, 1994].

The Application of Decision Support Systems to Extension

Growth in computer technology and electronic communication has an enormous potential to change the method of delivery of new technology and information to the farming community. However, as historically characteristic with new technology, producers in general are taking a "wait and see" attitude. Survey results, from surveys conducted in 1995 by Saskatchewan Agriculture and Food, Communications Branch, show that only a small percentage of farm managers wish to receive technical information via computer technology.

About 30% of all farmers currently own a computer system. Of those, 10% use their computer system for obtaining information from sources such as the Internet and the FBMInet (Farm Business Management Information network). The majority of farmers use their computer system for bookkeeping, production planning, and budgeting. Most producers attending an Internet Open House, in the fall of 1995, at the Saskatchewan Agriculture and Food Rural Service Centre in North Battleford, were searching for commodity prices, market and weather information.

As useful and applicable agricultural decision support systems are developed, an increasing number of farm managers will make use of computer technology. In the short term, the importance of traditional methods of technology transfer must not be overlooked. Of the producers who access information electronically, 62% of survey respondents indicated they desire to continue to receive production information in conventional formats as well. Only 8% of respondents wanted information in electronic format exclusively.

Although most farm managers are not using their computers for production oriented problem solving, which may be a result of insufficient useful appropriate expert and decision support system software available, they are using their computers for financial decision making. Until decision support and expert system technology are successfully transferred by the "innovative" farm managers and extension personnel, to the general body of farmers, the PARI DSS will be most frequently used by the innovative farmers and "front-line" technology transfer people. These people will include university and government extension personnel, commodity and conservation group extension people, as well as private sector distributors and retailers, who many farmers rely on as information providers.

All people involved in technology transfer, whether it be public or private, are overburdened with information. Decision support systems, such as the PAR1 DSS, can assist in the quick retrieval of information and acquisition of knowledge. Decision support systems such as the Crop Protection Planner are frequently used now by both farm service retailers and extension agents.

Conclusion

With the reduction of government budgets, producers will be approaching retailers or private consultants more often for information and answers/recommendations pertaining to their production problems. Furthermore, farm managers will be forced to seek out more answers and information on their own. The PAR1 DSS software, whether it be located on the computer of the farm manager, retailer or consultant, will be able to support the decision-making process for problem solving. For example, PARI a decision support system agent such as the Weed ID (Weed Identification) can be an extremely powerful tool for producers or retailers when used in combination with an educational tool such as the Weed Seedling Identification Video. Nearly 50% of the producers who contact the Saskatchewan Agriculture and Food Rural Service Centres are seeking answers/recommendations and information on farm chemicals and crop protection.

Public extension and community colleges have a role in teaching producers how to benefit from the use of electronic information technology. Extension has always been involved in the adoption of new production technology. However, it is a relatively new concept to transfer computer technology to producers. When the PARI DSS is usable, public and private extension will play an important role in field testing the system, at which time the importance of decision support systems in technology transfer and extension programming will be fully understood.

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