THE ROLE OF EXPERT SYSTEMS IN CURRENT AND FUTURE GRAIN PROTECTION

WILKIN, Robin*; MUMFORD, John# and NORTON, Geoff#

*Ministry of Agriculture, Fisheries and Food
Central Science Laboratory, Slough
London Road, Slough, SL3 7HJ
England

#Silwood Centre for Pest Management
Biology Dept., Imperial College
Silwood Park, Ascot, SL5 7PY
England

Abstract

A computer based expert system has been developed to assist in solving problems associated with the storage of grain. During the development of this system a great deal of experience was acquired relating to the requirements of an expert system and the problems likely to be encountered during development and operation. It is concluded that systems need to be compatible with widely accepted computer hardware and that they should have the simplest possible user interface. System support and product liability are also identified as operational problems.

The future developments and improvements for the application of expert systems to grain storage are discussed. These include improved presentation, better simulation modelling and the automatic acquisition of data.

INTRODUCTION

During the storage of grain, many factors can influence the quality of the product. These factors frequently interact, making a complex ecosystem. In developed countries, economic factors are often of paramount importance and, at the very least, must be considered alongside biological parameters (Wilkin, 1985). Developing effective solutions to storage problems or producing strategies to avoid problems, is sufficiently complex to frequently require the intervention of a knowledgeable and experienced adviser.

Within the U.K. the number of specialist storage advisers provided by government sources has diminished by about 60% over the past 10 years and it seems likely that this decline will continue further. The shortage has not been made up by an increase in private sector advisers or consultants. This reduction in human resources has coincided with a doubling of the U.K. cereal crop, an increase in the complexity of the problems as a result of larger stores and pesticide regulations, and an increase in quality standards directly related to infestation.

Against this background, teams from the Central Science Laboratory, Slough, and Imperial College, Silwood Park, have investigated the use of computer-aided decision making or expert systems, for use in grain storage. However, this paper is not intended as a detailed description of the system that was developed, but is aimed at giving some general indications of the value of computer-based systems, the problems associated with their production and use, and the options for future development.

WHAT IS AN EXPERT SYSTEM?

An expert system is a model that mimics the diagnostic and perceptive functions normally performed by a human expert (Barr and Feigenbaum, 1981). Expert systems are largely computer based and it is the enormous developments in computing that have extended the scope and application of the concept of expert systems. In particular, the availability of low cost high powered personal computers, operating on a limited number of common formats, offer the possibilities of widespread use of expert systems in many fields (Jones, *et al*, 1984; Lemmon, 1986; Mumford and Norton, 1987).

Expert systems have particular application to areas where:-

i) the problem is well defined but requires scarce human expertise to solve,

ii) the data associated with the problem is incomplete, so a solution must be based, at least in part, on judgement, and

iii) there are a large numbers of factors (physical condition and pest population growth) that need to be considered before a solution is developed.

Expert systems are characterised by the way they mimic a human's reasoning process. In their simplest form, they consist of three basic components (see Fig. 1):-

i) a user interface,

ii) a knowledge base and

iii) an inference engine.

The user interface is a means of querying the user, adding information and specifying problems. The knowledge base is a series of facts and rules which encapsulate current expertise related to the problem area. The operation of the system is directed by the inference engine. Further enhancement of the system may include the use of sub-routines to model certain

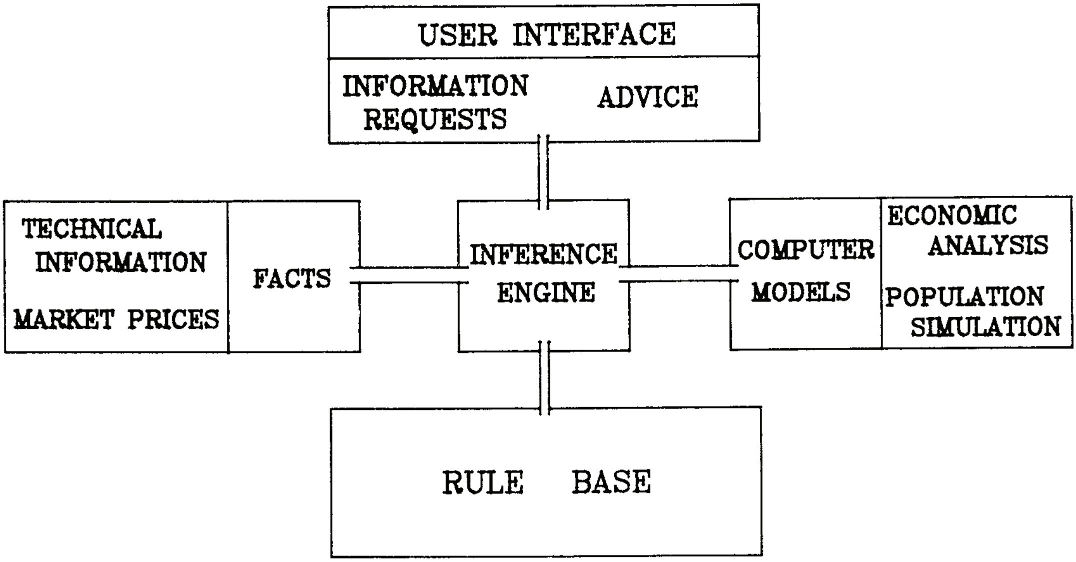

Figure 1. The major components of an expert system and their interactions.

scenarios, and calculate or model future consequences. Such enhancements of the basic system bring great advantages when two possible solutions are suggested for the same problem. Subroutines can be used to suggest which solution would have the highest chance of success or which would be the most cost-effective.

STORAGE APPLICATIONS

There are relatively few examples of expert systems being applied to decision making in food storage. This is surprising as examples of poor storage arising from bad management abound. Failure to obtain expert advice frequently seems to be a major factor in bad storage practice. Reasons for this include the lack of advisers, as already mentioned. However, an equally important factor is that grain storage often forms only a small part of the work activity of a store manager, so his personal expertise has to be split between commercial and staff management, knowledge of cropping, study of world markets, as well as a knowledge of safety and employment regulations. Thus, few storekeepers have expert knowledge of pest biology, precise details of the performance of control methods or a detailed knowledge of the long-term consequences of small changes in grain temperature and moisture content.

Modern developments in the field of grain storage, such as early pest detection and new approaches to non-chemical control, add to the potential value of expert systems. For example, there is a strong tendency for urgent control action, such as fumigation, to be triggered as soon as an insect is found in grain. Indeed, this course of action would fit with the commercial interests of some sources of storage advice. However, an expert system will take full account of the methods of detection and thus, the likely population density, the conditions of storage, the market requirements and many other relevant factors. Therefore, the advice given can be much more specific. It may be that the problem has no commercial consequence and can be ignored, or that low cost but slow acting, physical control options can be employed.

The ability of an expert system to act as a selective data base for relevant information, offers additional opportunities to make up for the lack of knowledge of storekeepers. This information can be used to explain the solutions offered by the system, to support the storekeepers of decisions, and may also provide the basis for improving general understanding of storage. One secondary, but still important function of expert systems can be via training "games" in which hypothetical problems are run through the system.

PROBLEMS ASSOCIATED WITH SYSTEM DEVELOPMENT

Our experience in the development and use of expert systems would suggest that there are a number of fundamental considerations that have to be considered before system development can begin. The most important concern the basics of the hardware used and its interface with the user.

If an expert system is to be successful and widely used it must operate on readily available, industry standard computer hardware. It seems unlikely that in many applications, users will be prepared to purchase computers expressly to operate a storage expert system. In many parts of the world this can be interpreted as a requirement to operate on IBM compatible personal computer systems. This has immediate implications for the design of the final expert system. A second and equally important requirement is that a system should not require any computer skill to operate. The majority of potential users will have little, if any knowledge of the operating system that controls the computer: the computer merely being a tool. This principle must apply to an expert system and again this requirement has implications for the construction of an expert system. Basically, users do not wish to be aware of the complexity of the program: they just wants results.

Major problems encountered by the authors in the development of a storage expert system were access to experts and the quality of available data. The shortage of expert storage advisers has already been commented upon. The first ingredient of an expert system is the knowledge base derived from human experts. However, advisers may often base their advice on rather fragile or ill-defined rules and make up for the deficiencies by on-the-spot reactions to developments. Properly structured expert systems can only function given a sufficiently comprehensive rule and knowledge base to cover all the eventualities that they are likely to meet. Surprisingly, a number of shortcomings were also encountered in the published. Most notable were the lack of precision in respect to the action of chemical control measures under a range of temperatures and against a range of pests, and the extreme difficulty in expressing the results of some pest detection methods in terms that could be related to the need for action on the part of the storekeeper.

Once a system has been developed and tested, two major problems still remain:

i) how to distribute and support the system

ii) how to cover product liability.

User problems and queries are inevitable with any computer software. Therefore, some form of support system must be made available to ensure that the system is used to full advantage. A telephone help line would seem the simplest approach, with assistance provided to cover computer based problems, as well as the interpretation of the storage data presented by the computer. Difficulties associated with product liability can be much more daunting, especially to a small team involved in developing a system. However, the law relating to giving advice apply to computer-based systems and the designers of the system could be liable to legal action if damage arose from its use. The value of a 5000 tonne bulk of grain is such that the theoretical level of damages could be enormous and, thus the cost of product liability insurance could also be high. Interestingly, it appears to make no difference to liability whether or not a charge is made for the system.

FUTURE DEVELOPMENTS

The expert systems currently in use or under development in the storage area must be considered as very early examples and all have the potential for considerable improvement. In addition, new research is yielding data that are ideal for incorporation in expert systems. However, the most immediate improvements may be in the form of the user interface and the system presentation.

The general availability of high resolution displays and fast, high capacity computers allows options such as accurate depiction of insect pests, facilitating better identification. There is also the possibility of using an animated display of a problem to give users a more easily assimilated idea of, for example, the rate at which a problem would develop if left unchecked. The importance of the visual impact of the user interface cannot be emphasised too strongly and developments in this area will hasten the general acceptance of expert systems.

Once a system is in use in a storage system it can become a data base, collecting and storing information about the storage environment and problems experienced, fed in by the user. Such record keeping can aid strategic planning and the accurate estimation of storage costs. An obvious extension of this principle is to establish direct links between an expert system and remote sensors recording the temperature and moisture content, and, perhaps even the signals from some pest detectors. Given access to such information, an expert system could both record and interpret data. The system would then only alert the user if changes occurred that indicated a potential problem. The system might also have direct control over an ambient air cooling system or a controlled atmosphere generator and their use would be linked to the results of data analysis carried out by the expert system.

One advantage of expert systems over human advisers that is not yet fully exploited, is the ability of computers to perform complex calculation very quickly. It would be feasible for an adviser to look up published data for an insect species and calculate changes in the level of population that would occur over time for a given set of conditions. However, this is rarely done because of the time required and the fact that, to be of real value, the calculations have to take account of changes in conditions over time. It would be relatively easy to build sub-routines into an expert system so that such calculations could be made. The sophistication of this could be increased further by the use of formulae that model insect growth and allow good estimations to be made of the effects of a very wide range of temperatures and moistures. Work reported by Armitage *et al* (1990) shows the potential to develop such models for insect development and the effects of cooling on population growth and decline.

The development of an expert system involves a great deal of work. The introduction of such a system into the practical storage environment requires further effort and commitment of resources. However, the basic biology of pests and the physics of grain storage are common throughout the world. It seems feasible to take an expert system developed in one country and export it to another geographic area. It would be necessary to change data on climate and, perhaps also on local quality requirements and regulations controlling the use of pesticides. However, these changes are relatively minor in comparison to the development of a new system. Language problems could be largely overcome with the next generation of expert systems by making greater use of graphic symbols rather than words. Solutions to problems could be given as numbers that could be checked against a manual in the appropriate language. Thus, the resources needed to develop a complex expert system could be more readily justified by the application of the system to a very wide range of storage environments.

CONCLUSIONS

There is an obvious role for computer based expert systems in grain storage. They allow the maximum use to be made of scarce human resources and offer a way of providing good technical advice to a wide audience at minimum cost.

Expert systems will never replace human experts as computer based systems rely on the input of a human adviser to establish its rule and knowledge base. They do, however, allow a human expert to be even more expert by, for example, reminding them of additional factors that need to be considered. They also are of great value in supporting and directing the decision making of less expert advisers.

Developing an expert system is a good method of identifying gaps in data. This, in turn, can help with the direction of research projects, particularly in relation to their priority and cost effectiveness. It seems rather surprising that so little interest is being shown in this function of expert systems in relation to stored products or other areas of agricultural research.

If a new system is to be both widely accepted and successful, great care must be taken to ensure that it is compatible with hardware that is in widespread use and that all the key requirements of the users have been met. Some form of market survey is, therefore, essential before even the basic design can be started. However, the collection of this data is often not easy as our experience would suggest many potential users have only a very hazy idea of there requirements from an expert system. Hence it may be necessary to produce a limited function "mock-up" to gauge user reaction. In addition, the rapid pace of development in computer technology can rapidly render market research out of date.

There are many options for further development of expert systems. Fortunately, hardware developments make many of the ideas proposed in this paper readily attainable. This suggests that the development and use of expert systems to improve the quality of grain storage will become an important point of interface between the computer programmer and the storage entomologist.

Acknowledgements

The initial funding that allowed development work on an expert system to start was provided by the Home-Grown Cereal Authority, Cereal Levy. The authors would like to acknowledge the major part played in the development of their expert system by Dr T Denne and the assistance that he received from A. Richards. We are also indebted to the efforts of Kim Amos and to other colleagues for help in collecting data and checking the system.

REFERENCES

Armitage, D M, Cogan, P M and Wilkin, D R, 1990. Reducing costs of bulk grain storage. *Proc. 5 int. working Conf. stored Prod. protect.* Bordeaux 1990, In press.

Barr, A, Barr, E A and Feigenbaum (eds) 1981. The handbook of artificial intelligence. Vol 1, William Kaufman.

Jones, M J, Northwood, P J and Crates, D 1984. Expert computer systems and videotex as aids to cereal disease control. *Proc. 1984 British Crop prot. Conf. - Pests and Diseases, Brighton,* 641 - 646.

Lemmon, H 1986. Comax: an expert system for cotton crop management. *Science 233;* 29 - 33.

Mumford, J D and Norton G A 1989. Expert systems in pest management: implementation on an international basis. *AI Applications,* 3; 67 - 69

Wilkin, D R 1985. Pest damage in stored grain. *Chemistry and Industry,* 3, 71 - 75

LE ROLE DES SYSTEMES EXPERTS DANS LA PROTECTION ACTUELLE ET FUTURE DU GRAIN

D.R. WILKIN (1), J.D. MUMFORD (2) et G. NORTON

(1) ADAS Central Science Laboratory
London Road, Slough Berks SL3 7HJ, England
(2) Imperial College, Silwood Park
SL5 1PY Ascot, Berks, England

Résumé

Un système espert, le "Grain Pest Adviser" (GPA) a été conçu pour aider à résoudre les problèmes occasionnés par les ravageurs dans les stocks de grains. Ce système, constituant l'aboutissement de 4 années de recherche et de développement, permet de poser le diagnostic et de choisir les solutions appropriées. Un progiciel, inclus, d'analyse financière permet de sélectionner la meilleure alternative en toutes circonstances. Le logiciel contenant une large base de connaissances d'informations encyclopédiques portant sur les ravageurs et leur élimination, est accessible à l'utilisateur, de même qu'un utilitaire de conception de stratégies. L'emploi du GPA permet d'envisager une approche plus fine de la gestion intégrée des ravageurs et donne la possibilité d'améliorer la qualité du grain, de réduire les coûts de stockage et de minimiser l'introduction de pesticides. On envisage également de connecter aux systèmes experts les connaissances sur la vie des ravageurs. Le GPA peut être utilisé pour la formation.

Le succès de ce type de système démontre sa valeur vis-à-vis des pratiques de stockage futures. D'autres travaux sont à envisager afin d'intégrer les systèmes experts dans la gestion quotidienne des grands magasins de stockage de telle façon que les données relatives à la qualité du grain soient récoltées et analysées et que certaines formations de routine soient effectués automatiquement.