PEST ACTIVITY PROGNOSIS IN RICE FIELDS USING FUZZY EXPERT SYSTEM APPROACH

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PEST ACTIVITY PROGNOSIS IN RICE FIELDS USING FUZZY EXPERT SYSTEM APPROACH

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ABSTRAK

Logik kabur merupakan satu bentuk perwakilan pengetahuan bagi konsep yang tak dapat ditakrifkan secara tepat tetapi bergantung kepada konteks penggunaannya. Sistem Pakar adalah program komputer yang menggunakan pengetahuan manusia untuk menyelesaikan masalah khusus yang memerlukan kepintaran manusia. Oleh kerana pengetahuan yang terlibat dalam pengurusan serangga adalah tidak lengkap dan kabur, maka logik kabur diintegrasikan ke dalam sistem pakar untuk mengendalikan penaksiran anggaran. Sistem Pakar dan Logik Kabur mempunyai kelebihannya tersendiri dan gabungan kedua-dua teknologi yang membentuk sistem pakar-kabur dapat meningkatkan keupayaan sistem (Herrmann, 1996). Berdasarkan keupayaan logik kabur dan sistem pakar, peramalan aktiviti serangga di sawah padi menggunakan pendekatan pakar-kabur telah dibangunkan untuk menyediakan maklumat kepada petani dan penyelidik melalui Internet. Oleh kerana beras merupakan makanan ruji rakyat Malaysia dan Kedah merupakan kawasan utama penanaman padi di Malaysia, kajian ini memfokuskan kepada aktiviti serangga di sawah padi. Dalam MyPEST, jenis serangga yang mengakibatkan kerosakan pada tanaman padi ditentukan oleh sistem pakar, manakala Logik Kabur digunakan untuk meramalkan tahap aktiviti serangga. Ini penting supaya rawatan awal dapat dilakukan sebelum kerosakan bertambah buruk. Sistem MyPEST membantu pengguna dengan mengendalikan rundingan pakar yang dikawalselia oleh sistem pakar dan logik kabur untuk peramalan dan menguruskan ketidakpastian data menggunakan pembolehubah lingistik. Sistem berasaskan web ini juga membantu petani dan institusi pertanian untuk menguruskan ladang dengan cekap dan dapat meningkatkan kualiti serta kuantiti beras yang dihasilkan. Dalam kajian ini, proses peramalan menggunakan lebih daripada satu attribut telah dikaji. Dapatan kajian menunjukkan sekiranya lebih daripada satu atribut terlibat, graf keputusan 3-dimensi yang kurang tegar dihasilkan. Penentuan jenis serangga adalah dalam fasa pertama MyPEST dan diikuti oleh peramalan aktiviti serangga yang dikenalpasti. Sistem ini telah disemak oleh pakar serangga di MARDi dan disahkan membawa manfaat kepada penyelidik di MARDI, MADA dan DOA khususnya dan petani secara keseluruhan.

ABSTRACT

Fuzzy Logic (FL) is a form of knowledge representation which is appropriate for notions that cannot be defined precisely, but depends upon its context. An Expert System (ES) is a computer program that uses human knowledge to solve problems in typical tasks, which normally requires human intelligence. As knowledge involved in pest management is imperfect, vague and not completely reliable, fuzzy logic is integrated in this expert system to deal with the approximate reasoning. Expert system and fuzzy logic have their own significant capabilities the combination of both technologies that forms a fuzzy-expert system or a hybrid system could increase the systems performance (Herrmann, 1996). Due to the capability of fuzzy logic and expert system, pest activity prognosis in rice field using fuzzy expert approach was developed to provide information to the farmers and researchers through the Internet. Since rice is the main staple food of the Malaysian and Kedah is known as 'rice bowl' Malaysia, therefore this study focuses on the pest's activity in the rice fields. In MyPEST, the type of pest that causes damage to the rice plant is determined by the expert system. On the other hand, Fuzzy Logic approach is used to forecast the pest activity level. This is important so that early treatment or action can be applied before damage to the plant becomes worst. The system helps the user by managing the consultation which is performed by the expert system and fuzzy logic to make prediction and dealing with the natural and uncertainty data using linguistic variables. This web based application system also helps the farmers as well as agriculture institution representatives to manage farm successfully and to improve the quality and quantity of rice production. In this study, the forecasting process using more than one attributes was explored. From the findings, if more than one attributes involved, the less rigid 3-dimensional decision graph was produced. The identification for the type of pest is also involved in the first phase of this system which followed by the activity forecasting based on the identified pest. The system has been verified by MARDI entomologist and the system is confirmed to benefit the researchers at MARDI, MADA and DOA particularly, and the farmers at large.

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Only God knows everything!

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CHAPTER 1

INTRODUCTION

This chapter briefly explains the background of the project that mainly involves the integration between fuzzy logic and expert system to form a fuzzy expert system in order to utilize the advantages from both approaches. The problem statement, objectives, significance of the project and scopes are also presented in this chapter.

1.1 Background Study

Fuzzy Logic (FL) is a form of knowledge representation which is appropriate for notions that cannot be defined precisely, but depend upon its context. It enables computerized devices to reason more like humans. Fuzzy logic is an excellent means to combine Artificial Intelligence methods (Zadeh, 1993). The advantage of fuzziness dealing with imprecision fits ideally into decision systems; the vagueness and uncertainty of human expressions is well modeled in the fuzzy sets, and a pseudo-verbal representation, similar to an expert's formulation can be achieved. In a sense, fuzzy logic resembles human decision making with its ability to work from approximate data and find precise solutions.

An Expert System (ES) is a computer program that uses human knowledge to solve problems in typical tasks, which normally requires human intelligence. Expert systems were designed to reason through knowledge to solve problems using methods that humans use. One of the key characteristics of an expert system is the explanation facility. With this capability, an expert system can explain how it arrives at its conclusions. The user can ask questions dealing with what, how, and why aspects of a problem. The expert system will then provide the user with a trace of the consultation process. The explanation facility helps the expert system to clarify and justify why such a digression might be needed.

However the conventional expert systems are developed using two logic values based on crisp rules. As knowledge involved in pest management is imperfect, vague and not completely reliable, therefore fuzzy logic is integrated in this expert system to deal with the approximate reasoning. Its application becomes mandatory to manage the uncertainty in the expert system (Zadeh, 1983; Zadeh, 1996). Since expert system and fuzzy logic have their own significant capabilities, the combination of both technologies that forms a fuzzy-expert system or a hybrid system could increase the systems performance (Herrmann, 1996).

To date, Hybrid Intelligent System (HIS) is more preferable to any single intelligent system approach (Kuciauskas *et al.*, 1998; Manner and Joyce, 1997; Herrmann, 1996). HIS refers to any integration of at least two AI techniques such as neural network and fuzzy logic (neuro-fuzzy), neural network and expert system (neural-expert), fuzzy logic and expert system (fuzzy-expert), neural networks, genetic algorithm and expert system or neuro-fuzzy-expert. The type of hybrid system to be used depends on the problem to be solved.

Prognosis has been used in medical applications. Prognosis is defined as a forecast of course of disease (Coulson *et al.*, 1990). Since prognosis requires forecasting ability as well as the ability to explain why a phenomenon occurs, therefore artificial intelligent techniques that are required to perform prognosis must be able to forecast and provide reasoning. AI techniques that are suitable for prediction are neural network, fuzzy logic and case based reasoning. On the other hand, expert system and case based reasoning are good at providing explanation to intelligent system. In this study, techniques which have the forecasting and explanation abilities are required. For this purpose, fuzzy logic and expert system have been chosen to be integrated in a web based environment to demonstrate the used of hybrid system, on pest activity in rice fields.

Within the proliferation of internet usability, there is much effort to bring the agricultural community online in Malaysia. Focus on the Malaysian Agricultural sector was renewed following the Malaysia economic crisis in 1998 (Shariffaden, 2000). Malaysian Ministry of Agriculture has introduced the Third National Agricultural Policy 1998-2010 (NAP3). NAP3 (1999) identified several issues and challenges to help tackle the problem of foreign food dependency. It is expected that information technology will play an important role in the acquisition and dissemination of new knowledge and technologies to motivate the involvement of youth in the agricultural sector (Deraman and Bahar, 2000). Consequently, a new technological solution is needed to work in parallel with the government efforts to help educate and inform the farmers and smallholders about pests and their activities for specific crops. Currently, it can be said that there are a number of agricultural resource sites available on the Internet (Di, 2000).

Pest management in crops is a highly challenging problem and may yield losses if it is not handled properly (Saini *et al.*, 2000). Potential losses of up to 55% before harvest have been estimated, but these estimates often represent the worst case or highest levels of loss. Hence, there is a need of different technologies as well as awareness programs for effective, economical, environment friendly control of pests (Singh, 1990). Besides, the appropriate and optimal combination of control measures are used for cost effective and environment friendly control of pests (Atwal and Dhaliwal, 1997). As knowledge involved in IPM is imperfect and fuzzy logic has been successfully used for approximate reasoning in such cases, its application becomes mandatory to manage the uncertainty in the expert system (Zadeh, 1983).

1.2 Problem Statement

The current practice of pest management in Agricultural Department is by observing the data from the selected plot in rice fields. The Agricultural Department in Teluk Chengai Kedah is responsible to rice fields located in Kedah and Perlis that involves 78 000 ha with 440 sampling point. The responsible employee at this department will observe the sampling plot in each selected location and state in the paper form of data observation. This data collected includes the name of the pest found, the stage of rice plant, the water status in rice fields and the number of pest present in the plot. This data is stored in the system and used to calculate the level of damages caused by particular pests. All these information will remains in this department and institute. The report from the observation is used to counsel farmer the action should be taken.

Due to the imperfect, vague and not completely reliable of knowledge involved in pest activity and damage level in rice fields, it is difficult to measure the symptom occurrences with simply yes or no, or absence and presence notation. However, the existing expert system allows the user to answer the set of questions using the rigid crisp values (Saini *et al.*, 2000). In crops management, it is important to estimate the damage that has been affected by pests since the degree of damage will determine the activity of pests (Atwal and Dhaliwal, 1997). Therefore, there is a need of a forecasting tool that can predict the level of pest activity so that early treatments can be applied to crops before the damage becomes worst.

1.3 Objectives

The main objective of this project is to develop the fuzzy expert system for determining and diagnosing pest and its activity in rice fields. Specifically, the objectives of this system are:

i. To forecast the pest activity level in the rice field.
ii. To provide explanation facilities using expert system approach.

1.4 Significance of the Study

The pest activity prognosis in rice fields offers computerized fuzzy expert system in dealing with uncertainty information in a way to identify the kind of pests attack on the rice plant derived from the symptoms given by the farmers. The system allows the users to input percentage of symptoms in uncertainty forms (high, very high, medium) rather than the common form of yes/no or absence/presence form. The proposed system enables the users particularly the farmers and the MARDI representative to identify the pest that damages the plant. The system also allows the users to forecast a pest activity level in the rice field. This allows the farmers and MARDI representative to provide the treatment before the pest activities become worst. In addition, all the information and knowledge about the pests, treatment control measure and prevention steps are managed in the specific knowledge base. Apart form identifying the pest and its activity level, the system can be used as part of portal development for MARDI and MADA in particular and the farmer community as a whole

1.5 Project Scope

The scope of this project is to develop prototype fuzzy expert system for pest management in rice fields. Fuzzy system is expected to be used in handling uncertainty type of rules while expert system copes with the explanation and reasoning tasks. The integration of expert system and fuzzy system is aimed to utilized advantages of both approaches. This fuzzy expert system is specifically developed for pest management in the rice fields. The main target users for this system are farmers in prior and MARDI officers as well as the Agricultural Institute.

1.6 Thesis Overview

This thesis report is constructed into six chapters. The first chapter is an introduction chapter that explains the background overview, problem statements, objectives, significance of the study and scope. The second chapter discusses a related literature review while the system design and implementation is discussed in chapter three Results and conclusion is revealed in chapter four and five respectively.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

MyPEST is a Pest Activity Prognosis in rice fields that has been developed using Fuzzy Expert approach. Expert system and fuzzy logic have their own significant capabilities. Therefore the combination of both technologies that forms a fuzzy-expert system or a hybrid system could increase the systems performance (Herrmann, 1996). MyPEST offers computerize fuzzy expert system in dealing with uncertainty information in a way to identify the kind of pests attack on the rice plant derived from the symptoms given by the farmers. The system helps the user by managing the consultation session in order to forecast the pest activity. A set of questions will be asked through graphical user interface and helps user diagnose their given symptom to infer such a conclusion. The consultation performed by the expert system also involved fuzzy logic when dealing with the natural and uncertainty data. This study focuses on the software development using hybrid AI technology and the employment of fuzzy expert system in agriculture domain typically in Malaysia.

Artificial Intelligence (AI) is a science and engineering of making intelligent machines, especially intelligent computer programs. The field of AI concerned with methods of developing systems that display aspects of intelligent behavior. These systems are designed to imitate the human capabilities of thinking and sensing. Turban (2001) explained that AI concerned with two basic ideas of human thoughts processes study and representing these processes via machines. It is often described in terms of various technologies developed over the last three or four decades (Watson, 1998). The technologies involved are logic programming, rule-based reasoning, neural networks, genetic algorithms, fuzzy logic, constraint-based programming and others. These technologies are characterized by specific programming languages or environments (e.g., Prolog or rule-based shells) or by specific algorithms and techniques (e.g., A*, the Rete algorithm or back propagation).

2.2 Expert System

An expert system is an interactive computer-based decision tool that uses both facts and heuristics to solve difficult decision problems based on knowledge acquired from an expert. The development of an expert system involves the construction of a problem specific knowledge base by acquiring knowledge from experts or documented sources (Turban, 2001). An expert system operates as an interactive system that responds to questions, asks for clarification, makes recommendations, and generally aids the decision-making process.

Complex decisions involve complex combination of factual and heuristic knowledge. In order for the computer to be able to retrieve and effectively use heuristic knowledge, the knowledge must be organized in an easily accessible format that distinguishes among data, knowledge, and control structures. Therefore the expert system is constructed in modularity to enable the system to perform effectively. The basic components of an expert system are its internal knowledge base and its reasoning capabilities based on the contents of the knowledge base (Luo *et al*., 2002). Expert system development usually proceeds through several phases including problem selection, knowledge acquisition, knowledge representation, programming, testing and evaluation. Moreover, they are also has a characteristic of reasoning with uncertainty, and explanation of the line of reasoning. The reasoning capability in expert system is provided by an inference engine (Turban, 2001).

Expert systems were designed to reason through knowledge to solve problems using methods that humans use. The expert system rules utilize the concept of linguistic variables which are associated to fuzzy term set where each term represents a specific fuzzy set (high, low, medium). They are easy to understand and modify (Loncaric *et al.*, 1998). In expert systems, knowledge is represented in the form of rules that are used to carry out tasks usually performed by human experts (Dean *et al.*, 1995). The basis of such rules is the theory of propositional logic which uses propositional variables (true/false) and truth-functional propositional connectives, including conjunction, disjunction, negation, implication and logical equivalence. If axioms and rules of inference are provided, a sequence of inferential rules results in a proof. However, abundance of uncertainty and/or fuzziness degrades the performance of expert systems (Lee *et al.*, 1998).

Most applications of expert systems will fall into one of the categories such as interpreting and identifying, predicting, diagnosing and instructing and training. Well design systems imitate the reasoning process experts use to solve specific problem (Turban, 2001). . Such system can be delegated by the experts as knowledgeable assistants. Successful expert systems will be those that combined facts and heuristics and thus merge human knowledge with computer power in solving problems. To be effective, an expert system must focus on a particular problem domain

Durkin (1996) explained that Expert Systems have been successfully used in almost all application areas such as Agriculture, Business, Chemistry, Law, Medicine, Manufacturing, and Space Technology i.e. the problems, which involve diagnosis, control, interpretation, monitoring, planning, prediction, prescription etc. The experts, who are consulted to create the Expert Systems, being humans, their expressions are moderated by the terms such as *may be, can be, very likely* etc. This often results in a knowledge base, which for the most part is neither certain nor consistent. The classical two valued logic cannot cope up with such uncertainty and inconsistency, therefore Fuzzy Logic (Zadeh, 1983) has been employed to manage this issue.

Expert system seems like to be a part of human life. From the decade it has been applied until nowadays, there are many improvement has been taken to ensure the expert system goal are achieved effectively. Expert systems offer an environment where the good capabilities of humans and the power of computers can be. Expert systems in general are able to increase the probability, frequency, and consistency of making good decisions. It helps very much in distributing human expertise and preservation of scarce expertise (Turban, 2001). The scarcity of expertise becomes evident in situations where there are not enough experts for a task. Further, an expert system for a particular decision problem can be used as a stand alone advisory system for the specific knowledge domain perhaps with monitoring by a human expert. In addition, an expert system can decrease decision time making and improved the decision quality.

In recent years, research and development of the expert system fields of agriculture domain have been paid much attention by many countries (Saini *et al.*, 2000). At the beginning of development of the agriculture expert systems, the areas selected are applications to diagnosis the diseases and pests of various crops. The difficulty of problems confronting farmers like yield loses, soil erosion, diminishing market prices from international competition, increasing chemical pesticides costs and pest resistance and economic barriers hindering adoption of farming strategies necessitates that they become expert managers of all aspects of their farming operations. On the other hand agricultural researchers need to address problems of farm management and discover new management strategies to promote farm success. Numerical methods have failed because understanding about crop systems are qualitative based on experience and cannot be mathematically represented (Mann, 1992).

The expert system has been developed with an objective to provide the pest management decision support to the farmers through the Internet (Saini *et al.*, 2000). This has been used for the crops grown in the different Indian regions and has been tested for the real world situations using feedbacks from the IPM users as well as IPM experts. Pasqual and Mansfield (1988) developed a prototype ES for identification and control of insect-pests.

SOYBUG ES was developed by Beck *et al.* (1989) for insect pest management, which is meant for soybean crops grown in the US. Later, Batchelor *et al.* (1989) developed an expert simulation system SMARTSOY for insect pest management. SMARTSOY incorporated soybean crop growth model SOYGRO in its knowledge base. A PC based SOYPEST ES was developed for application to the Indian conditions and standard ES design (Saini *et al.*, 1997; Saini *et al.*, 1998). National Institute of Agricultural Extension Management (MANAGE) has developed an expert system to diagnose pests and diseases for rice crop and suggest preventive/curative measures (Rice Crop, 1991). The rice crop doctor illustrates the use of expert-systems broadly in the area of agriculture and more specifically in the area of rice production through development of a prototype, taking into consideration a few major pests and diseases and some deficiency problems limiting rice yield. This prototype is a result of joint effort by the experts from NIIT and computer professionals of MANAGES while the subject matter expert knowledge on rice pathology and entomology, has been obtained from Scientists of Andhra Pradesh Agricultural University (APAU), Directorate of Rice Research (DRR). An Internet-based Pest Alert and Management System for Oregon (ORPAS) have been developed to deliver real time pest alerts with expert advice (Bajwa *et al.*, 2003). This system provides framework to be readily extended to other crops. Virginia Integrated Pest Management Expert for Wheat was developed to combine wheat pest management into decision support (Warren, 1999). The inference engine designed analyzes specific crop information to determine potential risks of pest outbreaks.

Expert Systems will play a major role in the dissemination and application of useful knowledge leading to economic growth and higher standards of living. They are not only providing expert's knowledge to particular problems but are potentially powerful learning resources to help Expert System users to develop their own expertise. More productivity and employment in Agriculture is obvious through wider and more diverse applications of new scientific results.

2.3 Fuzzy Logic

Zadeh (1998) introduces the concepts of Fuzzy Logic to present vagueness in linguistics, and further implement and express human knowledge and inference capability in a natural way. The accuracy of the approximation in real system is highly influenced by the fuzzy inference engine. The design of fuzzy system mainly involved two operations of the derivation of the knowledge base and the selection of the fuzzy inference with Defuzzification process that the system will use to perform the fuzzy reasoning (Cordon *et al.*, 1994). Fuzzy set theory and fuzzy logic are mathematical theories widely used in artificial intelligence (Klir, 1995). Fuzzy rule-based systems and fuzzy expert systems are AI systems with the ability of mapping sub symbolic to symbolic knowledge with the aid of fuzzy mathematics (Yager, 1992). The real-world decision-making is too much complex, uncertain and imprecise to lend itself to precise, prescriptive analysis. It is this realization that underlies the rapidly growing shift from conventional techniques of decision analysis to technologies based on fuzzy logic. It was originally proposed as a means for representing uncertainty and formalizing qualitative concepts that have no precise boundaries (Hasiloglu *et al.*, 2003).

In order to develop such intelligent system embedded with some prediction and forecasting ability, there is a lot of effort needed. The successful development of a fuzzy model for a particular application domain is a complex multi-step process, in which the designer is faced with a large number of alternative implementation strategies (Garibaldi *et al.*, 1999). Fuzzy logic representations are more intuitively satisfying than classical Boolean (bivalent) logic, as well as more precise and compact compared to classical rule-based representations (Reynolds, 2001). The difference between probability and Fuzzy Logic is that probability measures the likelihood that a future event will occur, whereas Fuzzy Logic measures the ambiguity of events that have already occurred.

Fuzzy logics are a way of formalizing the symbolic processing of fuzzy linguistic terms, such as *excellent*, *good*, *fair*, and *poor*, which are associated with differences in an attribute describing a feature (Mendel, 1995). Much of the decision making in the real world takes place in an environment in which the goals, the constraints and the consequences of possible actions are not known precisely. Any number of linguistic terms can be used. Fuzzy logics intrinsically represent notions of similarity, since good is closer (more similar) to excellent than it is to poor (Watson, 1998). Garibaldi (1997) stated that in multi-valued logic truth values are represented by a single real number in the interval [0,1], where 0 represents false, 1 represents true and values between 0 and 1 represent partial truth. Whereas in fuzzy logic true and false are represented by fuzzy subsets over the interval [0.1] with arbitrary fuzzy subsets representing other intermediate truth values.

At present, fuzzy systems are being used in a wide range of industrial and scientific applications with the main application areas being fuzzy control, data analysis and knowledge based systems. Fuzzy controllers, for instance, model the control strategy of a human expert to control a system for which no mathematical or physical model exists. They employ a set of linguistic rules to describe the human behavior. The major benefits of fuzzy techniques are the convenient method to model technical systems and the good interpretability of the system description by using linguistic rules. However, the implementation of a fuzzy system can be very time consuming because there are no formal methods to determine its parameters (fuzzy sets and fuzzy rules). Therefore it is necessary to have algorithms which can learn fuzzy systems automatically from data.

Fuzzy logic has made successful work after its invention. It has proven to be a useful approach for attacking many domains of problems. However, this method had not gained popularity until recently. The advantage of fuzziness dealing with imprecision fit ideally into decision systems; the vagueness and uncertainty of human expressions is well modeled in the fuzzy sets, and a pseudo-verbal representation, similar to an expert's formulation, can be achieved (Hasiloglu *et al.*, 2003). Fuzzy logic avoids the abrupt change from one discrete output state to another when the input is changed only marginally. This is achieved by a quantization of variables into membership functions (Herrmann, 1995).

2.4 Fuzzy Expert System

Hybrid systems composed of AI approaches have shown quite remarkable results in diagnosis (Herrmann, 1995). A fuzzy expert system is an expert system that uses fuzzy logic instead of Boolean logic and a collection of membership functions and rules that are used to reason about data. Unlike conventional expert systems, fuzzy expert systems are oriented toward numerical processing. This expert system is extended to incorporate explicit handling of imprecision in the input data and uncertainty in the embedded knowledge. The system formed the basis of the fuzzy expert system. The existent crisp rule set was used to derive the initial fuzzy rule set, and to guide the initial choice of location of membership function for each fuzzy term (Garibaldi *et al.*, 1999).

In a fuzzy expert system, a rule will fire if its premise evaluates to a non-zero belief level. The output of the expert system is achieved when rules fired. In a traditional expert system, the rules either fire completely or not at all. This is because a traditional expert system uses "yes/no," "black or white" logic to evaluate the premise of each rule. Typically, only one rule fires for a given group of inputs, so this one rule completely controls the output of the expert system. In contrast, the rules in a fuzzy expert system fire to different degrees. Rather than an all or nothing response, the fuzzy rules produce "shades of gray" responses, depending on the degree of belief in the premise of each rule. In addition, more than one rule may fire for a given group of inputs, so the output of the fuzzy system may be the combined result of several rules.

There are a number of advantages of having this integrated approach. In contrast with conventional AI techniques which only deal with precision and uncertainty the guiding principle of hybrid systems is to exploit the tolerance for imprecision, uncertainty, low solution cost, robustness, partial truth to achieve tractability, and better rapport with reality (Zadeh, 1998). In integrating hybrid approach, the complexity of its design and development increased (Adlassnig *et al.*, 1982; Cohen *et al.*, 1988; Watanabe *et al.*, 1994) However, although the theoretical properties of fuzzy systems have been extensively investigated, the implementation of a fuzzy expert system in practice involves a great deal of pragmatic choices. This includes considerations for the type of inference methodology, rule set and fuzzy operators to determine an appropriate fuzzy model of the expertise for a particular application.

The fuzzy rule base approach to expert systems is explained by Zimmerman (1991). Kosko (1997) refers to the rule base as a "fuzzy associative memory" and describes the process of rule resolution as firing all rules partially and in parallel and take a balanced average. Following Zadeh's *principle of incompatibility*, information obtained at production system level is interpreted at society level in linguistic terms. The integrated fuzzy expert system explicitly represented both imprecision in the input data and uncertainty in the interpretive knowledge base.

Fuzzy logic lets expert system performs optimally with uncertain and unambiguous data and knowledge. With a fuzzy logic framework, one can efficiently implement linguistically expressed rules derived from expert (Hansen, 1997). Many research and development have been successfully made with this integration. Fuzzy expert-system architecture for image classification was proposed by Moraes, Banon and Sandri (1998, 2000, 2002). Maner and Joyce (1997) built a weather prediction system that obtained simple weather prediction rules from experts and weather almanacs, and implemented these rules in system using a fuzzy logic rule base. Sujitjorn *et al.* (1994) and Murtha (1995) separately built systems to predict fog at an airport. Hadjimichael *et al.* (1996) and Kuciauskas *et al.* (1998) together built a fuzzy system, called MEDEX, for forecasting gale force winds in the Mediterranean.

Another successful application of fuzzy expert system for Short Term Load forecasting has been reported in Hsu *et al.* (1992) whereby fuzzy set theory is used to model imprecision in temperature and operator's heuristic rules. The resulting system has better forecast accuracy since the system can update the forecasted load in real time using most recently available records.

Sugianto (1999) pointed out that the fuzzy set theory has been known to be an effective approach to cope with uncertainty or inexact statement. Such feature is useful, especially when formulated within an expert system. The hybrid can deal with fuzzy factors in load forecasting. Fuzzy ES is very effective in improving hourly load forecast accuracy. More than that it can improved accuracy using fuzzy rule-based approach.

Romahi and Shen (2000) developed an evolving rule based expert system for financial forecasting. Their approach was to merge fuzzy logic and rule induction so as to develop a system with generalization capability and high comprehensibility. In this way the changing market dynamics are continuously taken into account as time progresses and the rule base does not become outdated. They concluded that the methodology showed promise.

The fuzzy expert system has shown to be a good choice for solving image processing problems that cannot be easy modeled by conventional image processing techniques. An expert system can be used to formulate expert knowledge which is difficult to utilize in conventional algorithms (Loncaric *et al.*, 1998). The edema segmentation consists of two parts which are fuzzy feature extraction and fuzzy expert system for performing the actual segmentation. Edema segmentation is in general difficult because of very subtle grayscale variations.

A fuzzy expert system is adapted for product life cycle management as a means for representing uncertainty and formalizing qualitative concepts that have no precise boundaries. To support the modeling process, a fuzzy expert system is designed to determine whether a new product enters into market (Hasiloglu *et al.*, 2003). Presentation of a new product to the market at the best time shall provide advantage to the companies in competition and increase in share in the market.

Garibaldi (1999) present the application of the technique to a fuzzy expert system for the interpretation of the acid-base balance of blood in the umbilical cord of new born infants is presented. The Spearman Rank Order Correlation statistic was used to assess and to compare the performance of a commercially available crisp expert system, an initial fuzzy expert system and a tuned fuzzy expert system with experienced clinicians. Results showed that without tuning, the performance of the crisp system was significantly better (correlation of 0.80) than the fuzzy expert system (correlation of 0.67). The performance of the tuned fuzzy expert system was better than the crisp system and effectively indistinguishable from the clinicians (correlation of 0.93) on training data, and was the best of the expert systems on validation data.

2.5 Integrated Pest Management (IPM)

Sustainable agriculture is a key element of sustainable development and essential to the future well being of the planet. Sustainability aims to achieve adequate safe and healthy food production, improved livelihoods of food producers and the preservation of non-renewable resources (CropLife, 2003). The demands of a growing world population for food and fiber require world agriculture to produce higher yields from less cultivated land. IPM or Integrated Pest Management is a strategy of managing pests that is designed to meet individual's production goals in the most economically and environmentally sound manner possible using a combination of control tactics. IPM is a systematic, information-intensive approach which depends upon an understanding of the entire production system. It strives to use several complimentary tactics or control methods to manage pests which make the system more stable and subject to less production risks. IPM focuses on tactics that will prevent or avoid anticipated pest problems rather than remediate problems once they occur. IPM requires competence in three areas: prevention, observation and intervention.

The implementation of IPM principles and the practices in Malaysia was a gradual yet continual process. IPM had its beginning in the 1960s when several entomologists became increasingly concerned on the negative consequences of excessive use and misuse of pesticides in the plantations. Then the IPM concept was gradually put into practice in other crops: rubber (Rao, 1969), cocoa (Wood 1971; Conway, 1971), oil palm (Wood 1971) and rice (Lim, 1970; Jusoh *et al.*, 1980). To date, the IPM approach has created measurable impacts in the various crops in Malaysia. It can be said that development and promotion of IPM rests mainly with governmental agencies like DOA and MARDI, especially for non-plantation crops. On the other hand, private research and development set-ups belonging to major plantation agencies are usually involved with IPM of major pests of plantation crops.

In Malaysia, Rice is the 3rd most widely planted crop after palm oil and rubber. In 1999, rice marketable surplus are 1.6 million metric tones. Since rice is the essential food commodity, continuously rice supply is needed. Rice production in this country is not being able to meet this demand even though the commodities depend on rice food energy. The lower quantity and quality of rice production cause the industry of rice production fail to meet the demand. Due to this reason, many researcher and institution of paddy in Malaysia contribute to help enhancing the competitiveness and profitability in agriculture and forestry. Recently, most of the farmers in this region are gradually moving away from the image of the traditional farmer to that of an entrepreneur farmer (Deraman and Bahar, 2000). Government has emphasized that there is a need to strengthen the competitiveness of Malaysian agriculture and the sector investment. The need to ensure adequate supply of safe, nutritious and high quality food at affordable size inspired many agricultural institutions to contribute on this research area and development. This institution intends to help farmer to cultivate this plant commercially. MARDI and MADA are the institution that contributes much in this area.

The proposed pest activity prognosis in rice field system employs fuzzy logic and expert system approach. It attempts to provide the amenities to the user especially rice farmer and researcher in this field and to identify the kind of rice pest that attacked their crops by giving the symptoms occurred on the plant. This system would infer a decision on the kind of pest and level of activity through the Internet. For study and reference purposes, a Malaysian Agriculture Research Development Institution (MARDI) has been chosen as case study to develop this system. This institution is one of the research institutions that contribute much in the agriculture area in this region.

CHAPTER 3

SYSTEM DESIGN AND DEVELOPMENT

This chapter explains the design and fuzzy expert system development for pest activity prognosis. This task involved the integration between two AI techniques, expert system and fuzzy logic. The fuzzy logic approach is used to determine the type of pest and its activity level while the expert system will be used to provide explanation to the users. The web application system aims to provide information to users through the Internet. This system is different from any available software for pest management in terms of its features. Firstly, the forecasting task for determining level of pest activity is based on one attribute. In this project more than one attributes were considered during forecasting task. Secondly, this system introduces the fuzzy logic approach in order to deal with the uncertainty and to reduce the rigid ness of the previous expert system approach. The integration of two AI techniques is to take advantage of the benefits of such system as well complementing each other. While fuzzy logic is good at uncertainty and vagueness data management, the expert system contributes much in reasoning and explanation capability.

This system starts when users choose a prognosis button on the main interface of this system. Several questions related to pest symptoms and signs of damages are displayed and answers from users are required by the system in order to perform the functions requested by the users. The first level of the prognosis process determines the type of pest that causes the damage to the rice plant based on the system provided by the user. The next stage focuses on the level of activity performed by the pest identified in the first level. When using the system, the users answer the questions by selecting the appropriate checkbox input that represents the yes or no answers. If users choose to select the yes answer (tick the checkbox), then users need to indicate the value of damages using the slider bar input function. This input value is divided into 3 categories of fuzzy labels such as low, medium and high condition. The value is later used for fuzzy inference tasks. The damage and level of pest activity is represented in percentage form of 0.0 to 1.0. In summary, the overview of the system is shown in Fig. 3.1.

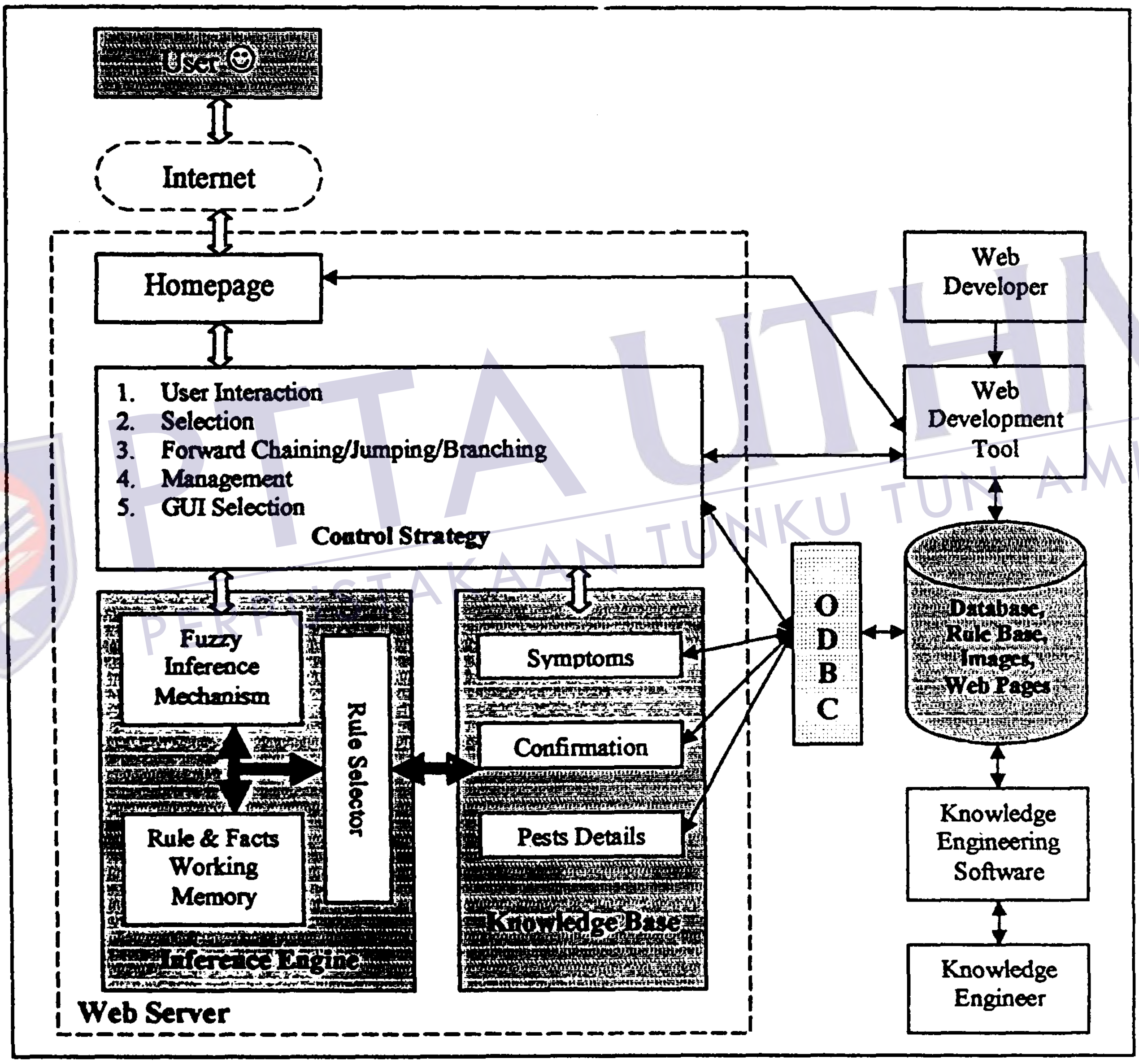

Figure 3.1: Pest Activity Prognosis in Rice Fields using Fuzzy Expert System Overview (MyPEST)

3.0 System Development

The development of an expert system involves the construction of a problem specific knowledge base by acquiring knowledge from experts or documented sources. The lengthy of developing process for expert system can be expedited using expert system shell. This system was developed using Knowledge Engineering (Durkin, 1994) methodology. The tasks are divided into 6 major phases, and the detail descriptions of each phase are illustrated as Fig. 3.2.

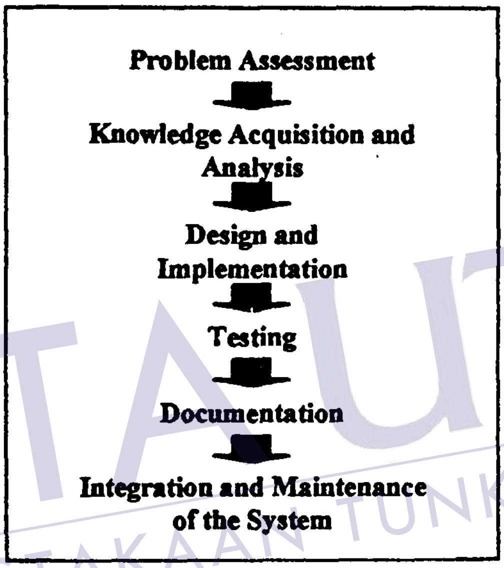

Figure 3.2: Knowledge Engineering (Durkin, 1994)

3.1 Problem Assessment

This phase concerns on the assessment of the applicability of an expert system to domain problem in this case the pest management in the rice field. In order to produce an acceptable system, the pest management must be clearly defined so that the system is able to achieve the objective of system development. The important attributes that govern the prognosis process in the rice field must be identified. It is also crucial to identify the selected approaches that are suitable to overcome the problems exist in pest management.

3.2 Knowledge Acquisition and Analysis

The knowledge acquisition process in which expert knowledge is coded into the knowledge base is time-consuming, difficult and constitutes one of the primary bottlenecks in expert systems development. Experts have difficult times capturing their knowledge for an expert program. Knowledge Acquisition is the process of extracting, structuring, and organizing knowledge from one or more sources (Turban, 2001). It is the one of major activities in knowledge engineering process. Knowledge engineering involves the cooperation between the domain human expert and knowledge engineer who assign to make explicit the rules that a human expert uses to solve problem. According to Bebenham 1998, knowledge engineering process includes five major activities which are knowledge acquisition, knowledge validation, knowledge representation, inferencing, and explanation justification.

Knowledge acquisition involves the process of getting and gathering information from human expert in a particular area, which then put into the computer. The process to knowledge acquiring is known as bottleneck in the expert system construction. It involves some efforts from knowledge engineer and experts which communication is an important factor to be considered. Since knowledge engineer has less knowledge of the domain compared to an expert, transferring expertise into a program might be crucial. It needs cooperation between both parties to avoid misunderstood and wrongly coded.

For this project the expert identified is the MARDI's entomologist and officer in the agriculture department. The experts gain their knowledge based on the theoretical and apply it in practical in the labs and rice field as their study platform. In the pest management, the expert able to identify which symptoms corresponds to pest or disease. They match this symptom with specific kind of pest and suggest treatment to control the damages caused by the pest. The information and knowledge gathered from the experts is about the signs of pest, damages to the plant, control measures and management principles. The other related information is also collected. As mention before, there is slightly less contradiction between the facts in the documented sources and expert knowledge. Instead of the ability to memorize and infer the solution, human expert make inference faster than manually refer to the books source. The documented source used in this process is a MARDI journal and International Research Rice Institution (IRRI) journal. In present work, knowledge has been obtained from numerous different sources such as published literature, human specialists, users and existing models.

3.2.1 Published Literature on Pest Management

The preliminary study about the pest and its damages to the plant was conducted by reviewing and extracting knowledge from relevant publications. The information was then filtered and condensed in a form that can be easily understood. Published literature includes books, pest management guides, research papers, surveys and reports, pesticides databases and news letters (Atwal and Dhaliwal, 1997; Saini *et al.*, 1997; SOPA, 1998). Preliminary knowledge has been compiled from IPM books and research papers published in journals, as it most reliable. The journals include the research written by local MARDI researcher and the standard IPM and International Rice Research Institute (IRRI).

3.2.2 Expert Interviews

Subsequently interview session was arranged with MARDI's entomologist to get detailed information and knowledge. From the observation, there is no contradiction between the knowledge from documented sources and expert because human expert refers to same knowledge. From the interview, it is found that the frequency of pest occurrences differ based on the geographical location. The information and knowledge is gained from paddy expert and their published research. Two paddy experts were interviewed, they are an officer, En Abdul Razak bin Hashim and Pest Entomologist, En Nik Mohd bin Nik Salleh at MARDI, Kuala Chengal, Kedah. The interviewing session was also conducted at Pejabat Peladang Changloon, Kedah with En Hanifah bin Saidin and Agriculture

Assistant Officer (Department of Plant Growth Control and Quarantine) Mrs Wan Kalsom bt Wan Ishak, Teluk Chengai Kedah.

Expert interviews have been conducted as:

i. Expert interviews have been important for knowing about IPM in Malaysian especially in Kedah-Perlis region. Interviews have been useful to gather knowledge about the pest zone, pest culture, crop region and the real world experience.

ii. Preliminary knowledge collected from literature has been validated with knowledge elicited from the IPM experts at MARDI, Kuala Kedah.

3.2.3 Internet Search

Although the Internet provides relevant information for pest management, the information must be verified with the expert to validate the accuracy of the information. Apart from the information of pest management in rice fields, the information on the development and usage of web based application in this domain (Malaysia and international) is also gathered from the Internet. From the study, there is a potential to introduce pest management on the web to the farmers in general and to Malaysian farmers in particular.

In the top level of Internet search engine, Yahoo or Google is preferable. However, in pest management there is number of websites that provide information and specific search engine such as www.knowledgebank.irri.org. In Malaysia, TaniNet has been developed to provide on-line information and services on agriculture and biotechnology. It is also provide searchable information on agricultural biotechnology. This website can be accessed at www.taninet.com.my.

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