ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

FACULTY OF COMPUTER AND MATHEMATICAL SCIENCES

DEPARTMENT OF COMPUTER SCIENCE

A Web based Expert System for Diagnosis of Disease and Pest in Ethiopian Coffee

By

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List of Acronyms

EIAR	Ethiopian Institute of Agricultural Research
KB	Knowledge Base
GUI	Graphical User Interface
WM	Working Memory
HTTP	Hyper Text Transfer Protocol
URL	Uniform Resource Locater
UML	Unified Modeling Language

Exclusive summary

This paper presents a web-based expert system for Ethiopian coffee. Coffee is one of the major cash crop and major source of foreign currency for Ethiopia and contributes more than 35% of the total export earnings. It is cultivated in vast areas in the country.

In Ethiopia, farmers get information or consultation from extension workers who serve as mediator between farmers and experts. Extension workers obtain information from documents, manuals and during training. This information may not enough to respond users' question. At this time they need experts' assistance. But the experts are not always available.

This expert system is intended to help extension workers by solving the problems they faced when experts help is not available.

This project is a rule-based expert system which covers three main classes of problems namely coffee diseases, coffee insect/pests and weed, normally encountered in coffee. The system provides proper consultation for identifying the cause of disorder and recommendation for prevention mechanisms. The system has been evaluated by domain experts and the analysis result shows that, the system is acceptable.

KEYWORDS: Web-based expert systems, Agriculture, Ethiopian coffee, Coffee diseases, Coffee pest, symptoms and e2gRuleEngine expert system shell.

Chapter one

Introduction

1.1. Background

Coffee is one of the tropical cash crops which grow in over eighty countries on four continents. There are different types of coffee in the world. Among these, coffee Arabica and coffee Robusta are the most widely grown, which covers 80% and 20% respectively and others Coffee Liberica and Excelsa together supply less than 1 % to market [5].

Arabica coffee originated in South-Western massive highlands of Ethiopia called Kaffa, more specifically from a district called Buno around 10^{th} century [1, 3]. Starting from that time it becomes known all over the world. In 14^{th} century Yemen used coffee as beverage and also she spread it to Middle Eastern countries in the 15^{th} century across Arabian Sea to India.

Coffee is the major source of foreign currency for Ethiopia and contributes more than 35% of the total export earnings [7] which involve 5 million farming families in production and processing. Thus, it is a cornerstone in the export economy of the country and it supports directly or indirectly the livelihood of 15 million people [6]. Ethiopian coffee accounts 4% of the world's production and 2% of the global export to all destinations. Ethiopia is Africa's largest coffee producer and 8^{th} in the world; producing close to 0.4 million tons annually and 95% of the coffee comes from around one million smallholder farmers, whose average land holding is about 0.5 hectare [8,9].

Nowadays coffee is closely associated with the Ethiopian culture because Ethiopia is known by its unique coffee ceremony all over the world. Every day each Ethiopian takes at least a cup of coffee. For instance 44% of the total production is consumed locally [2].

Even if, Ethiopia is the origin of coffee and has a long history, coffee still grows wild in Ethiopia's mountain forests. Today in Ethiopia smallholder farmers plant coffee in four different ways. These are, forest coffee, semi-forest coffee, garden coffee and plantation coffee which contributes 10%, 34%, 35% and 21% of the total product supply respectively. This sector is

characterized by traditional method of production and low level utilization of modern technology use [9].

In Ethiopia, the Ethiopian Institute of Agricultural Research (EIAR) is responsible for conducting research and supply of improved agricultural technology and popularization of improved technologies through extension workers [9] to enhance farmer's productivity and production.

The Jimma research center under (EIAR) is actively engaged in producing several coffee technology packages in addition it make recommendations on insect/pest and disease management, agronomic and soil fertility management for proper management of coffee production. To facilitate the transfer and utilization of these research outputs, Ethiopia has adopted and experimented several approaches of coffee extension interventions [9].

Arabica coffee prefers deep, friable, well drained and slightly acidic soils with a pH of 4.5 to 6.5, an elevation ranging from 1,200 to 2,300 meters above **sea** level and a well distributed rainfall of more than 900mm per annum. In addition, the provision of shade, pruning, fertilizing, pest and disease control and soil and water conservation need to be integrated to achieve a sustainable production system [3].

1.2. Motivation

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 in a specific domain. The first expert system was developed during the 1960s and the area was in agriculture but now it is an emerging technology with many areas for potential applications. Past applications range from MYCIN, used in the medical field to diagnose infectious blood diseases, to XCON, used to configure computer systems. [4].

Expert systems have found wide applicability in problems of crop management in agriculture. Many expert systems have been developed in different countries for plant disorder diagnosis, pest/disease diagnosis, irrigation management and other production aspects.

But in Ethiopia, technologies of expert system or computer-based decision tool have not been explored yet in agricultural and food industries. Therefore, the implementation of expert system

in the sector will have a vital importance to increase the quality and productivity of coffee production. Not only this, the system will minimize the time and money that spend for training of extension workers.

1.3. Statement of Problem

In Ethiopia, agriculture is the most important enterprise providing employment for more than 85 percent of the country's population [10]. Coffee is the major export agricultural crop. Most of the farmers have inherited rich cultural practices in irrigation, pest/disease diagnoses and other systems, which follow a traditional agricultural system especially in coffee production.

According to[10],coffee disease causes 18-20% yield reduction, coffee pest causes 10% reduction and weed causes 12% reduction and lack of using the right type of improved coffee technology are some of the factors which limits the coffee productivity. In order to manage these problem, appropriate pest/disease symptom identification and rapid diagnosis, weed control and recommendation mechanism is essential.

Almost all Ethiopian farmers rely on information's from extension workers [11]. By considering this reality the government tries to train extension workers which serve as a mediator between the farmer and the specialists (researchers).

The extension workers obtain information on new technologies in the sector after extension documents are distributed [11] or during training. In all this way information is not easily available and may not respond the farmers need. At this time extension workers try to look specialists' assistance. However specialists are few and unable to devote adequate time to assist them. Moreover they have limited working memory and may forget crucial details of a problem. In addition, specialists may lie, hide, become inconsistent in their day-to-day decisions and even may die. Because of this the information they obtained may be useless for the farmer at the time.

Generally the way of obtaining information in the above method is time taking and does not respond farmers need on time it causes crop lose.

In order to alleviate this problem, there should be some mechanism that increases the availability and accessibility of expertise knowledge to extension workers and end user farmers consistently and on time. So web based expert systems were identified as a powerful tool with extensive

potential in agriculture and can fulfill the need for higher productivity and reliability of decisions because Internet is widely accessible and its applications are inherently portable which provides a development environment that is platform independent and widely available. Not only this, several Internet-compatible tools for expert system development is available [12].

1.4. Objective of the project

1.4.1 General Objective

The main objective of the project is to develop a web-based expert system which provides expert advice on pest/disease diagnosis and weed management on Ethiopian coffee agriculture.

1.4.2 Specific Objective

The specific objectives include:

- Conduct literature review to study similar works which are already implemented in different countries.
- Identify different types of coffee pests/disease and its symptoms with prevention method, and weed types and control mechanism.
- Identify both functional and non-functional requirements of the system.
- Designing the system on the basis of the identified requirements.
- Identify the tool that used to develop knowledgebase
- Develop knowledgebase.
- Develop the user interface of the expert system.
- Evaluate the developed expert system.

1.5 Scope of the Project

In coffee production there are three main stages. These are coffee nursery management, transplanting stage and harvesting and processing stage.

Coffee nursery management is the stage that concerns about seed selection, site selection, bed marking, sawing, watering and also nursery disease/pest control.

Transplanting is the process of planting the coffee tree to its final location. After transplanting coffee takes three to four years to get product, and most of the problems are faced at this stage like coffee disease, insect/pests that damages coffee bean, steam, leaf, root and soon.

Harvesting and processing is concerned about collecting the coffee cherries and transforming fresh coffee cherries into clean, green bean of 12% moisture ready for export or for roasting.

The scope of coffee expert system is limited to the development of expert system for transplanting stage that provides expertise advice on how to identify pest/disease and diagnosis, recommendation about weed management.

1.6 Methodology

The sections present the following sub-sections data collection method, development tools and development process for this project.

1.6.1 Data Collection

To achieve the main goal of the project we collected large amount of data using different alternatives. One of this is through the interviews with agricultural specialist in the area. In addition to this, secondary resources (coffee diversity and knowledge, published by Ethiopian Institute of Agricultural Research, Technology for coffee and associated crops: Institute of agricultural research Jimma Research center and "**የቡና ልማት እና እንክብካቤ ዘዴ**": publishe by Coffee and Tea Authority of Ethiopia) and other documents are used..

1.6.2 Development Tools

For the development of this project, **e2gRuleEngine** expert system shell is used to develop the knowledgebase. This expert system shell replaces e2glite/e2gSwing inference engine in 2009 and the e2gRuleWriter decision table software was provide to construct the knowledge bases and free for private and commercial use [31].

java is used as a programming language, UML for system design, Macromedia Dreamweaver 8 for user interface design, web server to handle clients request from browser and other tools are used.

1.6.3 Development process

To develop the expert system we follow the phase stated in [17, 29]. The first step in the development of any expert system is problem identification. The problem here is a diagnostic problem aimed to identify ailments (disorders) in Ethiopian coffee using symptoms of diseases and pests.

The second one is knowledge acquisition: obtaining facts and rules from experts and documents. After we collect the important information we represent the knowledge in to machine-readable form. We use rule to represent the knowledge. Rules are currently the most popular method of knowledge representation not only this rules have uniform structure, provide “natural” mode of knowledge representation. The implementation and evaluation process will be discussed in chapter five and seven respectively.

1.7 Organization of the document

The rest of the report is organized as follows. Chapter two defines and describes concepts with regard to expert system, its environments, aiming to give a general view to the reader and presents review of research works on Agriculture area. In Chapter three and four we presented the analysis and design of the developed system respectively. The remaining three Chapters present Implementation, Evaluation and Conclusion and Future works.

Chapter Two

Literature Review

2.1 Ethiopian coffee

Ethiopia is the home and cradle of biodiversity of Arabica coffee seeds. More genetically diverse strains of Coffee Arabica exist in Ethiopia than anywhere else in the world, which has lead botanists and scientists to agree that Ethiopia is the centre for origin, diversification and dissemination of the coffee plant [13].

Coffee is the major export crop in Ethiopia and its contribution to the national economy is tremendous. In Ethiopia coffee grows at various altitudes ranging from 550-2750 meters above sea level. The coffee growing areas of the country are characterized by high rainfall, suitable temperature and humidity [9].

Despite the significant role coffee plays in the economic life of the country, the crop suffers from many production constraints. From the constraints, coffee disease, coffee insect pest and coffee weed are the major ones.

Coffee insect/pests are one of the factors which limit coffee production both in quality and quantity. In Ethiopia over 47 species of insect pests are recorded on coffee [9].

Coffee weed is common problem for all coffee growing areas. The warm, wet and humid conditions encourage the continuous growth of diverse flora. There are around 63 species in 23 families. Weeds are nuisance to coffee production because of their competitiveness [9, 10].

2.2 Expert system

An expert system is a computer program that simulates the thought process of a human expert to solve complex decision problems in a specific domain. An expert system provides advice derived from its knowledgebase, using a reasoning process embedded in its inference engine, the 'thinking' part of the system. There are different types of expert systems. Such as rule-based, frame based, case-based and model based [14].

Frame-based: knowledge is associated with the objects of interest and reasoning consists of confirming expectations for slot values. Such systems often include rules too.

Case-based: - previous examples (cases) of the task and its solution are stored. To solve a new problem the closest matching case is retrieved, and its solution or an adaptation of previous solution and proposed as the solution to the new problem.

Model-based: where the entire system models the real world, and this deep knowledge of the design and function of an object is used to diagnose equipment malfunctions, by comparing model predicted outcomes with actual observed outcomes.

All the above three are alternatives that used to develop expert systems, but most of expert systems are developed using rule-based and discussed in the next section.

2.2.1 Rule-based expert system

Rule-based expert system is an expert system which works as a production system in which much of the knowledge is represented as rules, that is, as conditional sentences relating statements of facts with one another [4,14]. Rule-based programming is closely related to classical logic usually first order logic and functional programming. First order logic is a symbolized theory in which each sentence or statement is broken down into subject and predicate. In a typical rule-based expert system, a rule consists of several premises and a conclusion. If all the premises are true, then the conclusion is considered true.

As shown in Figure 2.1 the architecture of rule-based expert system has four main components: working memory, knowledgebase, inference engine and user interface.

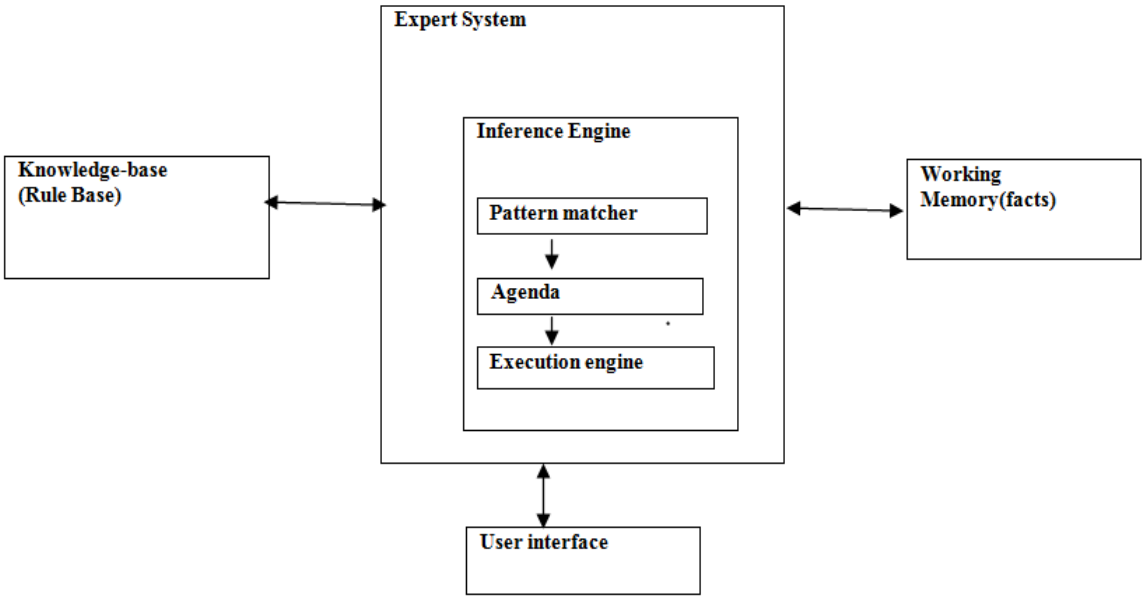

Figure 2.1 the architecture of rule-based expert system [4]

A. Working memory

The working memory (WM) represents the set of facts known about the domain. The facts are task –specific data for the problem. For example in medical expert system, the working memory could contain details of patient diagnosis [4]. The contents of WM changes based on problem situation and it is the most dynamic component of expert system. WM is used by the inference engine to get facts and match them against the rules. The facts may be added to the WM by applying some rules.

B. Knowledge Base

The knowledgebase is one of the components which consist of problem-solving rules, procedures, and intrinsic data relevant to the problem domain. In rule based expert systems, knowledgebase is also called production memory, rules are in the form of if-then productions.

According to [15], the general form of a rule is:

Table 2.1 Rule format for rule –based system

If
Conditions (predicate or premises)
Then
Actions or conclusions

Here the conditions also called antecedents are evaluated based on the contents of the working memory. Each antecedent of the rule checks if the particular problem instance satisfies some condition.

The rule that we write in the knowledgebase may alter the working memory. Using rule;

- Can add new elements(facts) to the working memory
- Can modify the existing element(facts)
- Delete the existing elements (facts).

C. Inference Engine

As the name implies the inference engine makes inferences. It decides which rules are satisfied by the facts, prioritizes them, and executes the rule with the highest priority. It controls the whole process of applying the rules to the working memory to obtain the outputs of the system.

According to [4], an inference engine works in discrete cycles as follows:

1 All the rules are compared to the working memory (using the pattern matcher) to decide which ones should be activated during this cycle. This unordered list of activated rules, together with any other rules activated in previous cycles, is called the conflict set.

2. The conflict set is ordered to form the agenda—the list of rules whose right-hand sides will be executed, or fired. The process of ordering the agenda is called conflict resolution. The conflict resolution strategy for a given rule engine will depend on many factors, only some of which will be under the programmer's control.
3. To complete the cycle, the first rule on the agenda is fired (possibly changing the working memory) and the entire process is repeated. This repetition implies a large amount of redundant work, but many rule engines use sophisticated techniques to avoid most or all of the redundancy. In particular, results from the pattern matcher and from the agenda's conflict resolver can be preserved across cycles, so that only the essential, new work needs to be done.

There are two types of inference: forward chaining and backward chaining [28].

- Forward chaining: the initial facts are processed first and keep using rules to draw new conclusions.
- Backward chaining: the hypothesis (or solution/goal) we are trying to achieve is processed first, and keep looking for rules that would allow concluding that hypothesis.

Example:

Rule 1: If A ^C => Y

Rule 2: If A ^ X => Z

Rule 3: If B => X

Rule 4: If Z => D

❖ To prove that D is true, given A and B are true.

In **forward chaining,** start with Rule 1 and go on downward till a rule that fires is found. Rule 3 is the only one that fires in the first iteration. After the first iteration, it can be concluded that A,B, and X are true. The second iteration uses this valuable information. After the second iteration, Rule 2 fires adding Z is true, which in turn helps Rule 4 to fire, proving that D is true.

In the **backward chaining** method, processing starts with the desired goal, and then attempts to find evidence for proving the goal. To prove that D is true would be initiated by first finding a rule that proves D. Rule 4 does so, which also provides a sub goal to prove that Z is true. Now

Rule 2 comes into play, and as it is already known that A is true, the new sub goal is to show that X is true. Rule 3 provides the next sub goal of proving that B is true. But that B is true is one of the given assertions. Therefore, it could be concluded that X is true, which implies that Z is true, which in turn also implies that D is true.

Whether an inference engine performs forward chining or backward chaining entirely depends on the design which in turn depends on the type of problem [15].

Inference engine has three main components: Pattern matcher, Agenda and execution engine [4, 15].

Pattern matcher: helps the inference engine to decide which rules to fire and when, by matching the current contents of the working memory.

Agenda: a component that helps to store fired rules. It is responsible for using the conflict strategy to decide which of the rules, out of all those that apply, have the highest priority and should be fired first. Finally, once your rule engine decides what rule to fire, it has to execute that rule's action part.

Execution engine is the component of a rule engine that fires the rules based on the priority in the agenda.

D. User interface

User interface is a part which supports communication between a user and the system. The user interface may be a simple text-oriented display or a sophisticated, high resolution display. It is determined at the time of designing the system. Nowadays graphical user interfaces are very common for their user-friendliness.

2.3 Expert system development process

In expert system development there are six main phases:[17,29] Problem Selection, Knowledge Acquisition, Knowledge Representation, Implementation, Evaluation and Maintenance.

A. Problem selection

To develop an expert system, first we need to identify the problem and understand the major characteristics of the problem that we have to solve in the expert system.

B. Knowledge acquisition

Knowledge acquisition is the process of obtaining facts and rules from the domain expert so that the system can draw expert level conclusions. The process of knowledge acquisition is difficult especially in case if the knowledge engineer is unfamiliar with the domain. There are two major sources for knowledge acquisition: experts and documents. Knowledge acquisition is the major bottleneck in constructing expert system and also time taking and determines the quality of expert system. The main reason for this bottleneck is communication difficulties between the knowledge engineer and the domain expert.

C. Knowledge representation

The major objective in this phase is to take the acquired knowledge and translate it into machine-readable form. There are many different methods of knowledge representation: semantic net, cases, frames and rules are the most popular method of knowledge representation currently. The reason for its popularity is: their modularity, their uniform structure and rules provide a “natural” mode of knowledge representation.

D. Implementation

The first decision to be taken after the design of the system is the selection of the implementation tool to be used. The criteria of selection depend on the facilities required by the system version being implemented. We will discuss briefly in Section 2.5.

E. Evaluation

The main goal of evaluation is to assess the quality, usability, and utility of the expert system from the point of view of human experts and target users. According to [16] there is no universal standard for expert system evaluation. But there are some points that we can consider:

- Is the system user friendly?,
- Does it give correct result?,

- Does it offer improvement?,
- Easy to learn and so on?.

F. Maintenance

Mainly concerned on knowledge change and updating. The effects of a change in one part of the knowledgebase may have devastating side effects in other parts. Care must be taken in order to ensure that the total knowledge of the knowledgebase has been upgrade and not degraded by changes. Methods for performing knowledgebase maintenance need to be developed in order to ensure knowledge integrity.

2.4 Expert system features

There are a number of features which are commonly provided by expert systems. Some shells provide most of these features, and others provide some of them. Features which commonly exist are: goal driven reasoning or backward chaining, Data driven reasoning or forward chaining, Data representation, coping with uncertainty, User interface and Explanations [15, 17, 18].

Goal driven reasoning or backward chaining is an inference technique which uses IF THEN rules to repetitively break a goal into smaller sub-goals which are easier to prove. Backward chaining is very good when all outcomes are known and the number of possible outcomes is not large. In this case, a goal is specified and the expert system tries to determine what conditions are needed to arrive at the specified goal.

Data driven reasoning or forward chaining is an inference technique which uses IF THEN rules to deduce a problem solution from initial data. This method involves checking the condition part of a rule to determine whether it is true or false. If the condition is true, then the action part of the rule is also true.

Data representation refers to the way that the problem specific data is stored and accessed in the system. For all rule based systems, the rules refer to data. The data refers the knowledge that we represent in machine-readable form. The data representation can be simple or complex, depending on the problem.

Coping with uncertainty refers to the ability of the system to reason out with rules and data which are not precisely known. For expert systems to work in the real world they must also be able to deal with uncertainty. Approaches used to handle uncertainty vary from system to system based on the type and cause of uncertainty. There are two types of uncertainty that we have to capture in rule based system [17]. Those are uncertainty in the data and uncertainty in the rule.

Expert systems typically use shallow reasoning using thumb rules or heuristics provided by the expert. These rules are not guaranteed to be correct always, which causes rule uncertainty. In most complex decision making processes, all the required information may not be accessible when required. Decisions have to be taken without knowing all the relevant parameters. This is called uncertainty with data.

Explanation refers to the ability of an expert system to explain them service. This is the system knows which rules were used during the inference process; it is possible for the system to provide those rules to the user as a means for explaining the results. There are two types of explanations that are used to explain the reasoning process to give recommendations [18]. These are Why and How explanation. That is why a particular question is being asked and how the system came to a particular conclusion.

Asking Why?

When the system asks the user, the user may ask "why you ask me this?". At this time the system explains the reason to the user by telling the goal of the question.

E.g. In medical expert system which identifies heart disease may ask the user "is the patient pregnant?" the user may say why? The system then starts to explain that it is needed to confirm the possibility of heart disease in the context of the evidence available.

Asking How?

When the expert system reaches to some decision, the user may ask the system, "how this conclusion is derived?". This helps to explain the reasoning process and generally the problem solving strategies.

2.5 Choosing the right implementation

In expert system development process, selecting appropriate developing tool is important part for successful implementation of the system. In this Section 4 different choices are explained as stated in [19, 22].

The first choice is coding from the ground up: this is simply means programming the inference engine from scratch and 're-investing the wheel'. It may be suitable for certain applications but it was totally inappropriate because of time and limited resources available in this case.

The second choice is use of suitable expert system programming languages: which already contain the inference engine and other extensions. The commonly known languages are:
Prolog: a backward-chaining artificial intelligence language. Prolog comes in several flavors', the latest even being visual, which provides possible integration with other visual type(event, GUI driven) programming languages.

CLIPS: the C Language integrating production system. It is very similar to LISP (the LIST Processing Language) using the concept of list.

The third choice is Web-enable expert system language, which is one of the best choices as it enable developer to easily integrate with web application. For example, prolog comes with a web enabled interface and several prolog java wrappers exist. Some of them are commercial and large in size and others are free but still in beta testing stages.

The last one is Web-enabled shell and a pre made user interface: in this choice expert system shell is a complete development environment for building and maintaining knowledge-based applications. It provides a step-by-step methodology, and ideally a user-friendly interface such as a graphical interface, for a knowledge engineer that allows the domain experts themselves to be directly involved in structuring and encoding the knowledge. Examples of shells include Drools, CLIPS, JESS, d3web, G2, eGanges, e2glite, e2gRuleEngine (new version of e2glite with e2gRuleWriter) and OpenKBM (initially developed as a replacement for G2) [19].

1.6 Related works

Many expert systems have been developed in different countries for plant disorder diagnosis, management and other production aspects but while reviewing related works done on expert system in agriculture, we could not found enough expert system work for local context. Especially there was no any attempt made in coffee disease and pest diagnosis. In this part we present some of the expert systems developed in agricultural field.

The history of expert system in agriculture traced back to 1980s.The first expert system was developed in 1983 called **PLANT/ds** developed for the diagnosis of soybean diseases in Illinois, USA [23]. A unique feature of the system is that it uses two types of decision rules:

1. The rules representing experts' diagnostic knowledge and
2. The rules obtained through inductive learning from several hundred cases of disease

SOYPEST: is an acronym for **Soy**bean **Pest** Expert System. This is an Integrated Pest Management (IPM) [20] and decision support system. The expert system has been developed with an objective to provide IPM decision support to the farmers through the Internet. This has been used for the crops grown in the different regions of India. Previously developed systems to SOYPEST were non-network (pc based) and non GUI but this one is web based with simple GUI. The web based SOYPEST expert system has been developed to identify the active pests and to calculate the activity of active pest and their diagnosis. To develop this system, fuzzy logic with crisp rule is used.

EXOWHEM: Expert system on Wheat Crop Management developed in India by Indian Agriculture system Research Institute (IASRI) with collaboration of two research institutes on wheat [21]. The system holds a collection of general principles that applied to solve problems related to wheat crop management and also capable to extend expert advice to farmers and researchers. The system tries to cover agricultural operations, variety selection, fertilizer application, insecticide/pesticide applications and also try to see economic benefits. The system accepts the users question and analysis it then gives an advice to the user.

To develop the system Expert System shell will be developed using appropriate scripting language to integrate fact and rules with the system .Suitable GUI's will be developed for user's to interact with the system inference engine through the expert system shell.

In this system, cultural practices and harvesting technologies are incorporated which specifies the process of cultivation and the appropriate method, machinery and time respectively.

The developed system encourages the dissemination of research findings and helps the farmers. Moreover, it reduces the load of experts and facilitate researches on wheat.

Citex: Expert System for Orange Production implemented at the Central Laboratory for Agricultural expert Systems (CLAES) in Egypt [22]. The system holds a collection of general principles that is used to problems related to orange production. The system concerns mainly on pre harvesting activities like farm preparation, irrigation management, fertilizer application and disease diagnosis.

The methodology followed in the construction of CITEX is Knowledge Acquisition and Documentation Structuring (KADS). It is a structured way of developing knowledge-based systems (expert systems). It was developed at the University of Amsterdam as an alternative to an evolutionary approach and is now accepted as the European standard for knowledge based systems.

COMAX: is a cotton crop management expert system developed by the USDA, Mississippi State University and Clemson University which can predict crop growth and yield in response to external weather variables, soil physical parameters, soil fertility, and pest damage [24]. The expert system is integrated with a computer model, Gossym that simulates the growth of the cotton plant. This was the first integration of an expert system with simulation model for daily use in farm management.

An Expert System for diagnosis of diseases in Rice Plant: this system is intended for the diagnosis of common diseases occurring in the rice plant [27]. The system facilitates different components including decision support module with interactive user interfaces for diagnosis on the basis of response(s) of the user made against the queries related to particular disease symptoms.

To develop this system a prolog based expert system shell ESTA (Expert System for Text Animation) is used. ESTA has the explanation facilities of the questions in the knowledgebase and for the given advice. ESTA contains the rules represented in its own syntax for its knowledgebase. It consists of the inbuilt facilities to write the rules that build the knowledgebase.

Such system is especially useful for those farmers who are not getting the agricultural specialists at any time for their help to control the problems in their rice plant.

SUBERMAX: is an expert system for potato storage which addresses only the early phases of storage and related concerns [25]. The system models the decision made by commercial potato storage managers during early storage of potatoes. SUBERMAX can take information on potato quality, bin environment, outside environment, bin facilities, and give recommendations and consultation on three areas. These are suberization preconditioning and anticipating which show how to manipulate bin facilities to maintain an ideal bin environment for maximizing potato quality during the early phases of potato storage. To develop this system an expert system shell that used rule based logic was used.

Generally this system serves as good medium for dispersing new information, gathered from research and field experience, throughout the potato industry.

Dr. Wheat: is a web-based expert system for disease and pest diagnosis in Pakistan wheat crop [26]. This system is a rule-based expert system mainly focused on two problems namely diseases and pests, normally encountered in wheat crop. The expert system is intended to help the farmers, researchers and students and provides an efficient and goal-oriented approach for solving common problems of wheat.

The expert system is constructed using e2gLite™ expert system shell available freely on the internet. This web-based expert system shell allows a JAVA interface to process its input and output sets.

Chapter Three

System Analysis

This chapter discuss about the current system, the functional and non- functional requirements of the system. Finally we will look at the system models (use case model, sequence diagram and activity diagram) of the new system.

3.1 Current system

Currently Coffee disease and pest identification activities are performed by extension workers in two ways. The first one is reading documents and manuals. The second one is consulting experts. This is very time taking and doesn't give on time service. To solve this problem we have developed web-based expert system which gives easy and fast information to users.

3.2 Functional requirement

It describes the interactions between the system and its environment independent of its implementation. The environment includes the user and any other external system with which the system interacts. It also describes the specific functions and tasks of the system. In light with this, the developed system is expected to provide the following functionalities:

- Identified coffee disease and insect/ pest that causes crop disorder
- Identified weed that occur in the field
- View coffee disease and insect/pest detail,
- updating the knowledgebase(may Add new, modify the existing one)
- Finally recommendation to control and prevent the identified coffee disease, insect/pest and weed.

3.3 Non functional requirement

This describes user-visible aspects of the system that are not directly related with the functional behavior of the system. Non-functional requirements include quantitative constraints. The following lists state the non functional requirements of the new system.

Usability the system shall provide help system that can describe and illustrate all system functions and how it works .This helps the user to easily understand the system.

Security the system should allow access to its knowledgebase to authorized person only.

User Interface the system will have graphical user interface through which the users interact with the system. The interface should be simple and easy to use.

Documentation: The documentation prepared has detail information on how to make use of the system and covers all use cases of the application. Within it, there is a section covering the user interface and how the system developed.

3.4 System Models

System model describes the structure and application of the system. This helps the analyst to understand the functionality of the system and models are used to communicate with customers (users). It consists of use case diagram, sequence diagram and activity diagram that describes the logical components of the system.

3.4.1 Use Case diagram

The above functional requirements can be expressed within the “Use-Case Model”, for better understanding of requirements elicitation. The main concepts of use case modeling are actors and use cases. An actor represents an entity (human or may be system) external to the system which communicates with the system in order to achieve certain goals. On the other hand, use case describes the functionalities and a sequence of actions that provides something of measurable value to an actor. Figure 3.1 shows the use case diagram of the system.

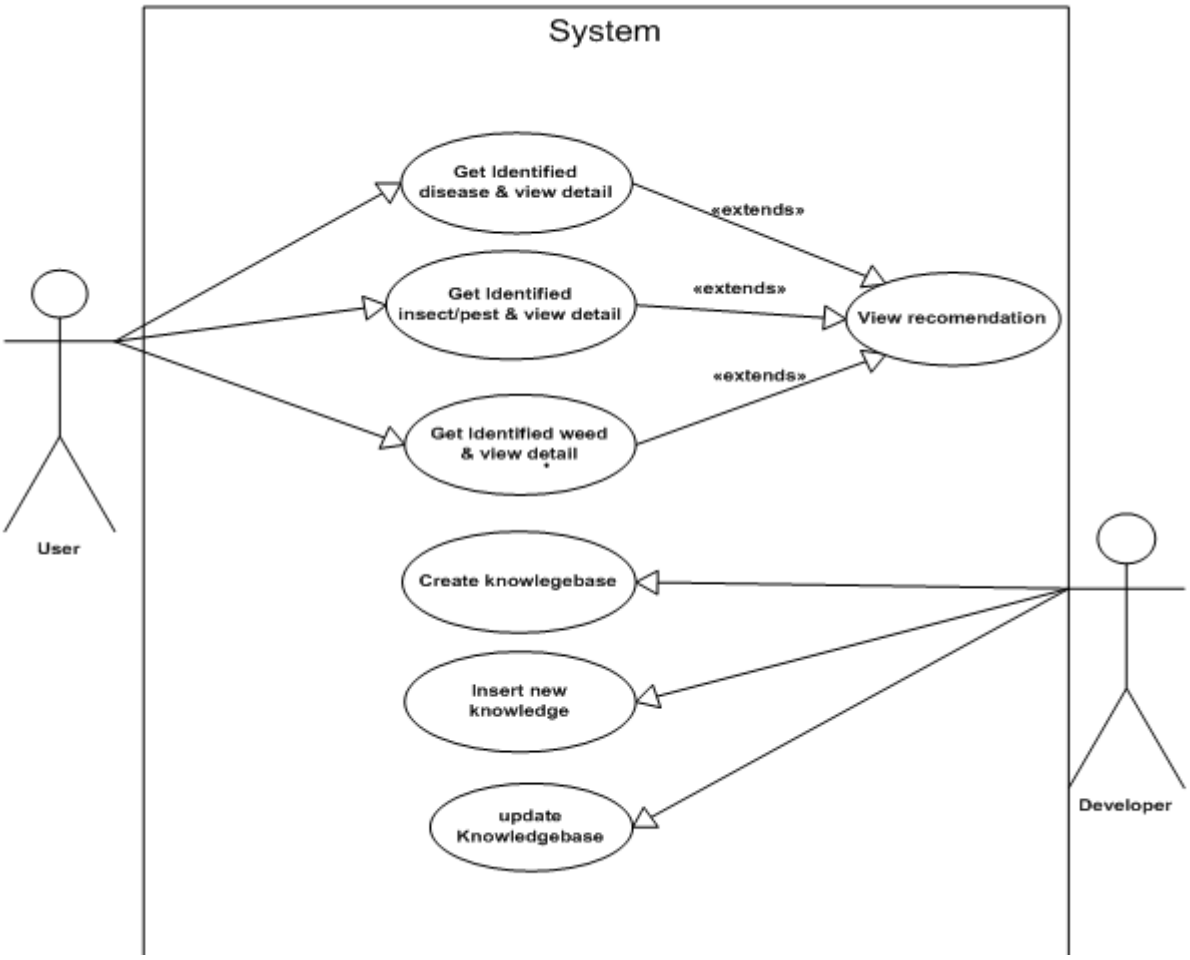

Figure 3.1 Use case diagrams

The next part describes the actors and flow of events for each use-case for the above use case diagram

1. **Actor Descriptions**

Name: User

Description: A user is a person who uses the system

Name: Developer

Description: A developer is a person who is responsible to update the system domain knowledge, create knowledge base and insert new data to knowledge base.

2. **Use case description**

This explains how the functionalities precede using natural language in a stepwise manner to accomplish the identified use cases in Figure 3.1

Use Case Name: Get Identified disease & view detail

Actor: User

Description: To identify diseases that is responsible for the observed disorder

Related Use Cases: View recommendation

Precondition: the user should open the site

Flow of Evens:

1. The user selects the advice category
2. The system displays a page with different options(pest management, disease management and weed management)
3. The user selects the disease management option
4. The system displays the main disease identification window.
5. The user confirms to proceed to the system.
6. The system request series of questions.(e.g. 1 At what weather condition the infection increase? A, dry B, humid, 2.which part of the plant is affected by the disease? A, coffee-berry, B, coffee –leaf, C, coffee-steam…)
7. The user response all questions
8. The system displays the disease that causes the disorder.
9. The user clicks underlined disease name to get more information
10. The use case ends.

Post-condition: the user will see the potential list of diseases that causes the disorder and detail information about the disease.

Use Case Name: Get Identified insect/pest & view detail

Actor: User

Description: to identify insect/ pest those cause disorder to the plant

Related Use Cases: View recommendation

Precondition: the user should open the site

Flow of Events:

1. The user selects the advice category
2. The system displays a page with different options(pest management, disease management and weed management)
3. The user selects the pest management option
4. The system displays the main insect/pest identification window.
5. The user confirms to proceed to the system.
6. The system request series of questions.(e.g. 1 At what weather condition the infection increase? A, dry B, humid, C, warm 2.which part of the plant is affected by the pest? A, coffee-leaves, B, coffee –beans, C, coffee-flower, D, whole-part…)
7. The user response all questions
8. The system displays the insect/pest that causes the disorder.
9. The user clicks underlined insect/pest name to get more information
10. The use case ends.

Post-condition: the user will see the potential list of insect/pest that causes the disorder and detail information about the insect/pest.

Use Case Name: Get Identified weed & view detail

Actor: User

Description: to identify weed those occurred in the farm and cause disorder to the plant

Related Use Cases: View recommendation

Precondition: the user should open the site

Flow of Events:

1. The user selects the advice category
2. The system displays a page with different options(pest management, disease management and weed management)
3. The user selects the weed management option
4. The system displays the main weed identification window.
5. The user confirms to proceed to the system.
6. The system request series of questions. (e.g. 1 what type of weed do you observe in the farm? A, Grass B, Sedges (grass-like), C, Broad-leaves 2.what characteristics does the weed have? A, tabular and joint steam, B, round, hollow flower steam …)
7. The user response all questions
8. The system displays the weed that occurred in the farm.
9. The user clicks underlined weed name to get more information
10. The use case ends.

Post-condition: the user will see the potential weed that occurred in the farm and detail information about the weed.

Use Case Name: View recommendation

Actor: User

Description: allow user to see recommendations about prevention or control mechanisms for identified disease, insect pest and weed.

Precondition: the user should open the site

Base Use Case: get Identified disease, get Identified Insect pest, get identified weed

1. The user selects the advice category
2. The system displays a page with different options(pest management, disease management and weed management)
3. The user selects one of the option
4. The system displays the main window for the selected option.
5. The user confirms to proceed to the system.
6. The system request series of questions. (as we see in the above cases)

7. The user response all questions
8. The system displays the identified disordered that occurred in the farm with prevention mechanism (cultural and chemical).
9. The use case ends

Post-condition: the user will get recommendation and control mechanisms for identified disorder.

Use Case Name: update Knowledgebase

Actor: Developer

Description: to update the knowledgebase

Precondition: the Developer should login to the server pc.

Flow of Event:

1. Open the directory that contains the knowledgebase.
2. the system open the knowledgebase with text editor
3. The developer updates the knowledgebase by writing rules
4. the developer logout and exit the system

Post-condition: updating the knowledgebase

Use case Name: Create knowledgebase

Actor: Developer

Description: to create new knowledgebase

Precondition: the Developer should login to the server pc.

Flow of Event:

1. Create the directory to store the knowledgebase.

2. the user opens text editor /e2gRuleWriter
3. the system opens the editor
4. the user write rules and integrate with the system
5. the developer logout and exit the system

Post-condition: create the knowledgebase

Use case Name: Insert new knowledge

Actor: Developer

Description: to insert new knowledge to knowledgebase

Precondition: the Developer should login to the server pc.

Flow of Event:

1. Open the directory that contains the knowledgebase.
2. the system open the knowledgebase directory
3. the user selects the module that he went to insert new knowledge(pest, disease or weed)
4. The developer insert the knowledge by writing rules
5. the developer logout and exit the system

Post-condition: inserting new knowledge to the knowledgebase

3.4.2 Sequence diagram

Sequence diagrams used to model the behavior of use cases by describing the way how objects interact to complete a task. The following figures show the sequence diagram of the system.

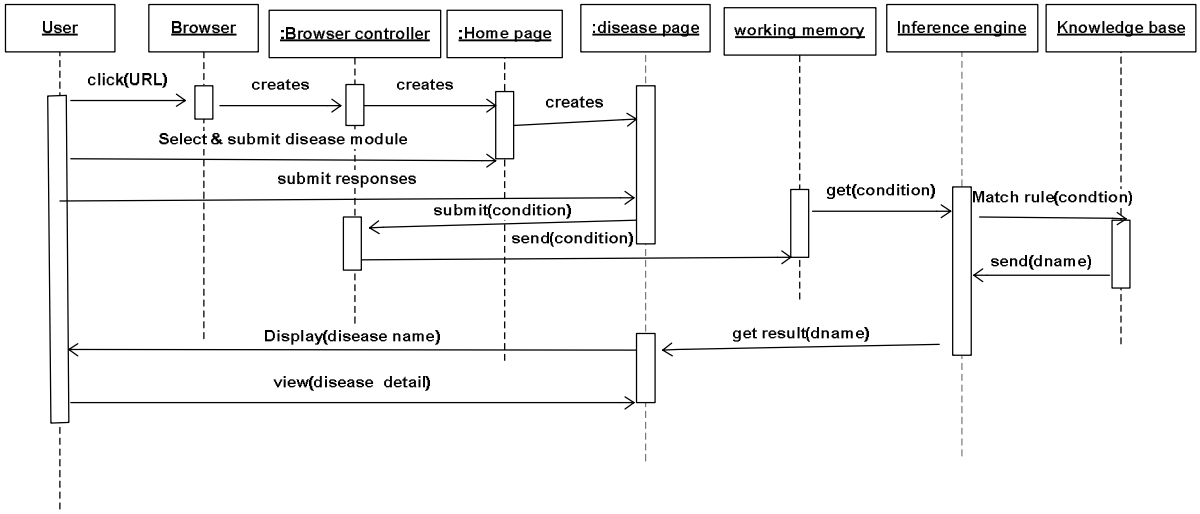

Figure 3.2 sequence diagram for use case" Get identified disease & view detail"

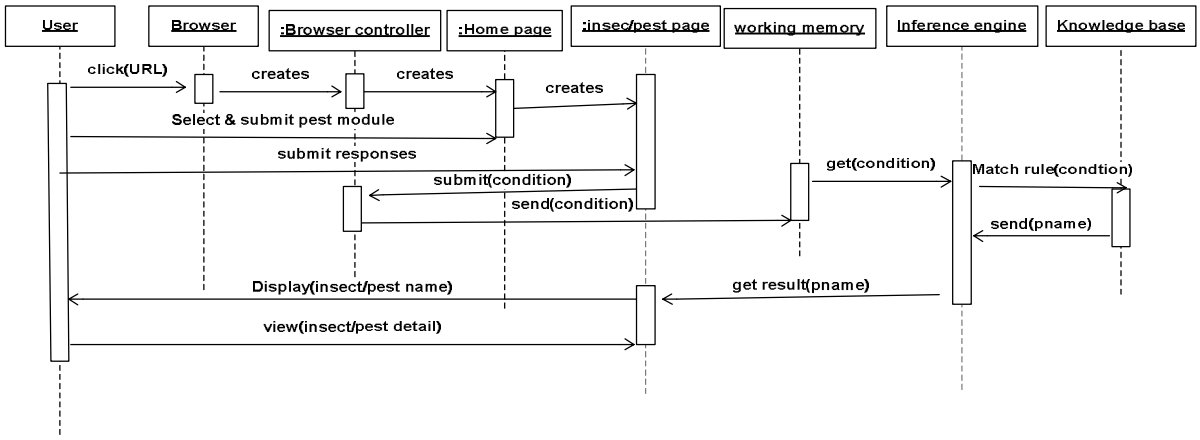

Figure 3.3 sequence diagram for use case "Get identified insect/pest & view detail"

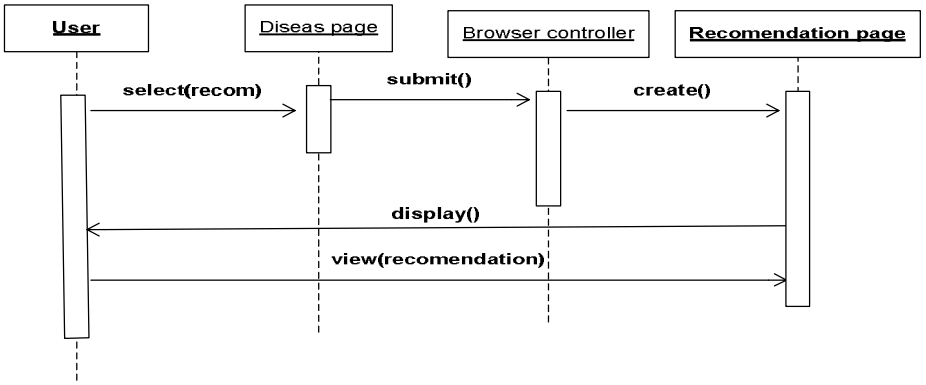

Figure 3.4 recommendation sequence diagram

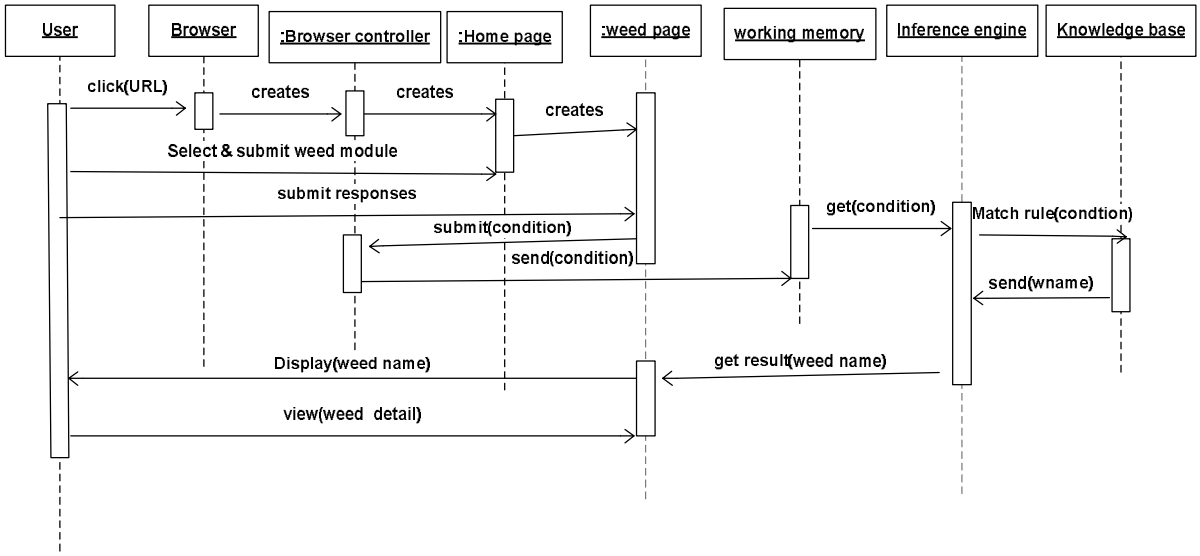

Figure 3.5 sequence diagram for use case"Get identified weed & detail"

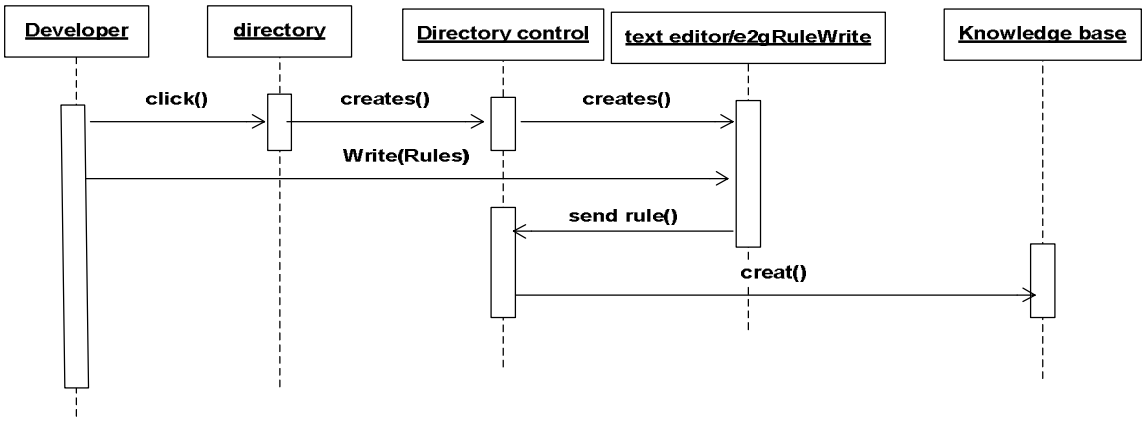

Figure 3.6 sequence diagram for use case “create knowledge base”

3.4.3 Activity diagram

Activity diagram describes the workflow behavior of a system. As shown in Figure 3.7 the diagram describes the state of the activities by showing the sequence of activities. It can show activities that are conditional or parallel.

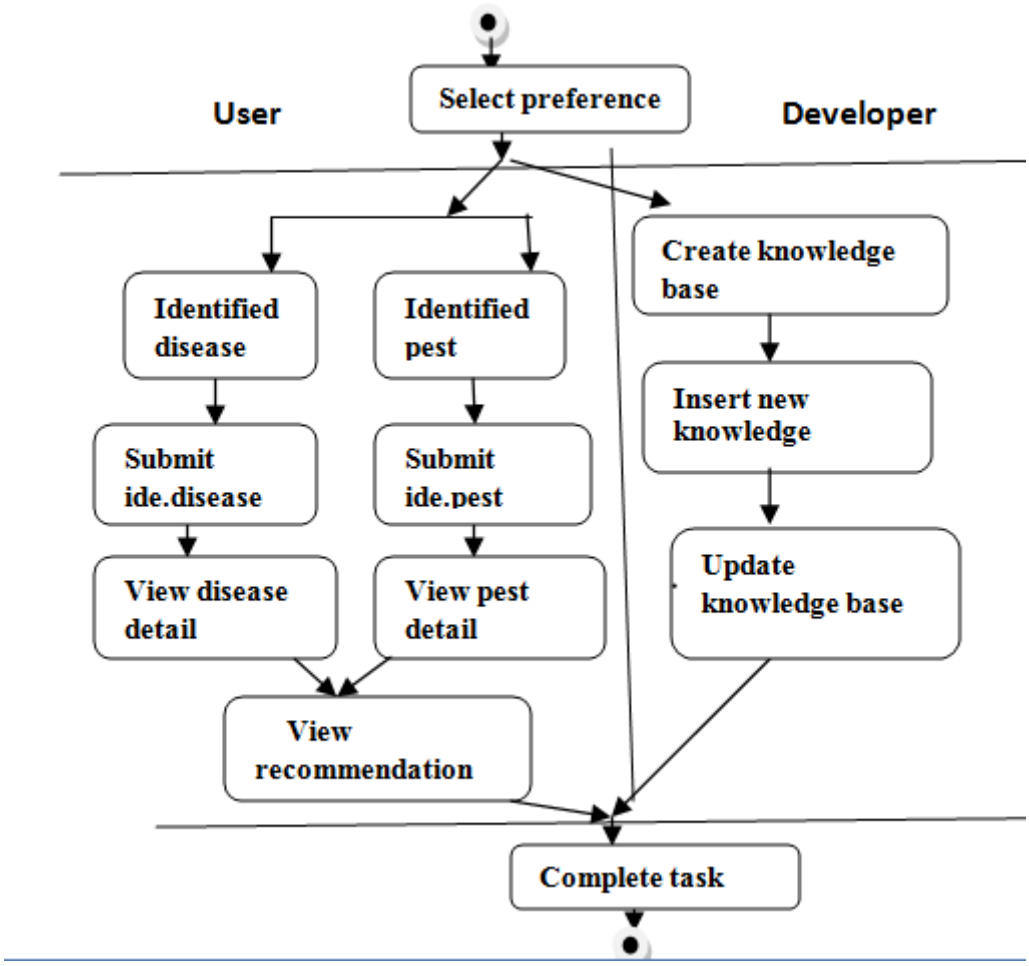

Figure 3.7 activity diagram

Chapter Four

System Design

In the previous chapter we have identified the functional and non-functional requirements of the system and produced the analysis model. Based on this analysis, the design of the system is presented in this Chapter. In a software development, system design is the first phase to get into the solution domain. First we will set the design goals and followed by the architecture of the system which is described in terms of its subsystem decomposition and deployment.

4.1. Designing Goals

Design goals are used to identify the qualities that our system should focus on. Many design goals can be inferred from the non-functional requirements or from the application domain. These are:

Portability: the system work in different platforms and easy.

Accessibility the system is accessible to any user who has Internet access.

End user criteria concerns about usability and user interface. From the end users' perspective the system should be designed in such a way that it is easy to learn and use and should be user friendly user interface.

4.2. Knowledge Acquisition

Knowledge acquisition is the process of obtaining facts and rules from the domain expert so that the system can draw expert level conclusions. To acquire the knowledge for our system we followed the knowledge acquisition procedures discussed in [8, 20] and the knowledge of various ailment of coffee and their symptoms were obtained from various literatures [9,10,30] and rules from domain experts that helps to identify specific disorder.

Based on the acquired information, we design different factor tables (refer to Appendix A, B and C). For example, the insect/pest factor table provides information about the affected part, symptom, insect color and suitable weather condition for production and attack.

4.3. **Knowledge** B**ase**

After we collected the required knowledge through knowledge acquisition process, the knowledge is represented as rules that the system can understand in the knowledgebase. In our system there are three main knowledgebase and one subsystem identification knowledgebase which helps the user to select one from the three. The knowledgebase are: insect/pest knowledgebase (insect/pest KB), disease knowledgebase (disease KB) and weed knowledgebase (weed KB) as shown in the system architecture knowledge base component in Figure 4.1

For coffee expert system we use a total of 34 rules. Table 4.1 shows the number of rules for each category of knowledgebase (refer Appendix F) for more detail.

Table 4.1 number of rules

Category(knowledgebase)	No. Rules
Subsystem identification knowledgebase	3
Disease knowledgebase	9
Insect/pest knowledgebase	15
Weed knowledgebase	7

The knowledgebase elements are: RULE, remark (REM), user prompt (PROMPT) and output (GOAL).

REM statement is used as a single line comment. These lines are ignored when the knowledgebase is processed.

RULE is defined by a RULE keyword followed by a short description of the rule enclosed in square brackets. This follows by the rule premise with keyword **If**. The logical expressions consist of an attribute name, any relational operator or any comparison quantity. The rule consequent is mentioned with keyword **Then**. Rule elements are not case sensitive. Attributes in e2gRuleEngine are String (text), Numeric and Boolean.

Sample rule: that we used in pest knowledgebase

RULE [B]//to start consultation

If [status]=false

Then [the diagnosis]="there should be disorder to continue “and

---

RULE [GCS]

If [status] =true and

[Condition]="dry" and

[afected part]="coffee-leaves “and

[symptom]:"yellowing leaves""honey-dew and ants that eats it" and

[color]="yes"

Then [the diagnosis]="Green-coffee-scale" and

When we represent in English like statement (natural language)

If pest is observed in the field

Weather condition is dry

The pest affects tree leaves

The tree leaves become yellow, honey-dew and ants occur

The pest has green color

Then the pest is “green-coffee-scale”

PROMPT command is used to interact with the user in order to ask question about a particular disease or pest. An example of prompt is given below.

PROMPT [afected part] ForcedChoice

"Which part is affected by the pest?"

"coffee-leaf"

"coffee-leave and berries"

"coffee-berries"

Here the PROMPT keyword has different parts; these are prompt name in square bracket, prompt type, question to ask user and response choices. Prompt types:

- YesNo (radio button true/false (Boolean) input
- MultChoice (text string radio button input)
- ForcedChoice (same as MultChoice without the "I don't know..." option)
- Choice (text string drop-down list input)
- Numeric (range-checked numeric input)

In the above example the name is [afected part], the type is ForcedChoice, the question is "Which part is affected by the pest?" and response choices are:

"coffee-leaf"

"coffee-leave and berries"

"coffee-berries"

"whole-part"

The GOAL is the objective of the system and defined after a rule is defined. When all GOALs are resolved (or it is determined they cannot be resolved) the consultation ends. At least one GOAL is required.

Example

The goal for the above rule, **RULE [**GCS**]** is

GOAL [The diagnosis]

4.4. Architecture of the System

The general architecture of the system is shown in Figure 4.1. The architecture presents the four main components of the system. These are: user-interface, knowledgebase, working memory (WM) and inference engine.

The user interacts with the system through user interface that runs on client's machine. Here the user sends its response (answers to the question raised by the system) via user interface to WM and then the memory holds the response as temporary data. After these the inference engine matches the data with the rule premises from the knowledgebase. Finally the result is return to the user via the user interface application.

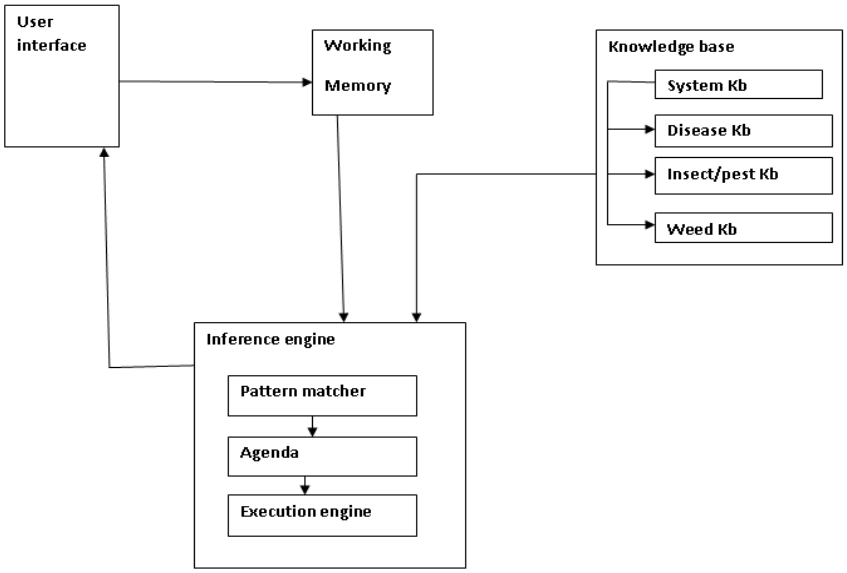

Figure 4.1 system architecture

The inference engine

The main objective of the inference engine is to forward/backward chaining to respond to user query with appropriate reasoning. It controls the whole system and it is the central part of the system.

The system collects relevant information from users and stores this information in the WM; by using pattern matcher, the inference engine matches all the rules in the knowledgebase to the

stored data in WM to decide/identify which rules should be activated. All activated rules are ordered to form agenda and fired by execution engine in order.

All the data that the inference engine uses to compare the rules' antecedent part are stored as a fact in working memory. The fact may be user response or other information that the system is working with. Here, the user responses to systems question are stored as fact in it, and then the inference engine uses it.

4.5. Subsystem Decomposition

Subsystem decomposition helps to reduce and simplify the complexity of the solution domain. The subsystem can be considered as packages that holds related class/objects. Web-based Expert System for Ethiopian coffee management system is the aggregation of different subsystems. As shown in Figure 4 .2 the main subsystem are disease management, insect/pest management and weed management. Each subsystem has its own knowledgebase and detailed html pages for more information.

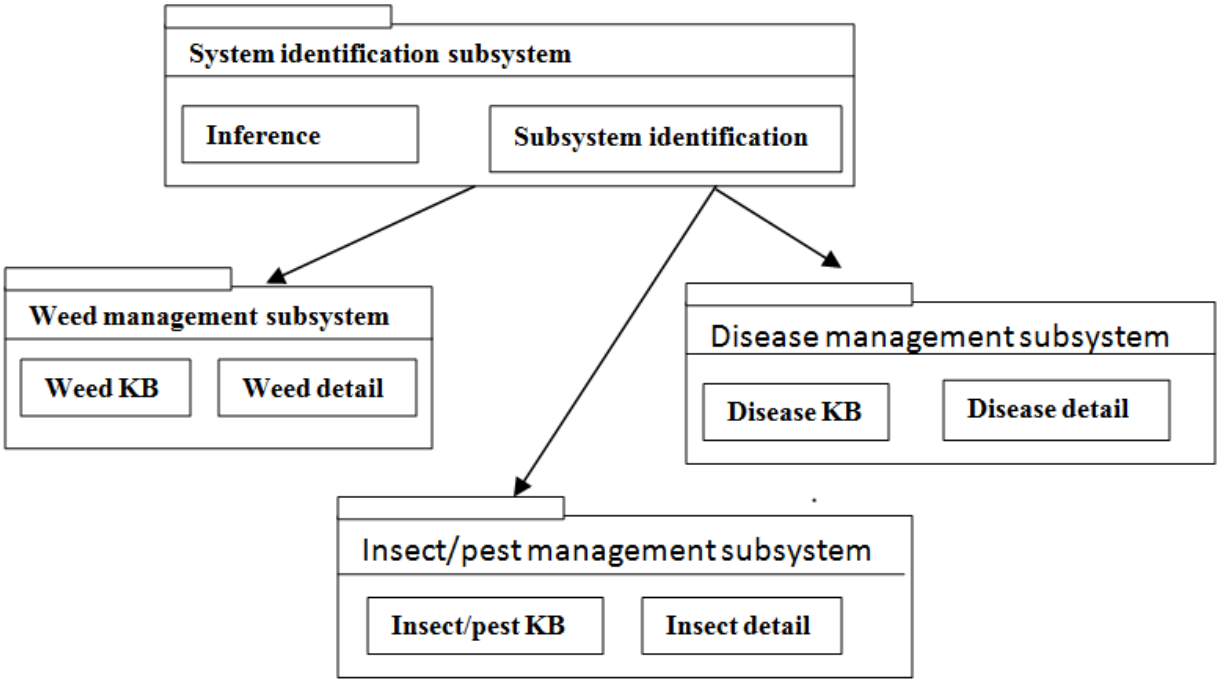

Figure 4.2 subsystem decomposition

4.5.1 System identification subsystem

This subsystem provides the appropriate interface to the basic subsystems of the system and allows the user to select the functionality. This subsystem hosts the inference engine that manipulates one of the KB at a time. Based on the users response it activates the respective subsystem and provide result back to the user. Moreover, this subsystem manages the WM.

4.5.2 Disease and insect/pest management subsystem

The responsibility of disease subsystem is to accept users' response to the question that the system request and store it in to the WM, then the inference engine try to match the rules with the stored data by the pattern matcher and create agenda. Finally the fired rule by execution engine provides the diagnoses with disease detail and recommendation for prevention mechanism. The insect/pest identification subsystem also follows the same prouder with disease identification subsystem.

4.5.3 Weed management sub system

This subsystem allows the user so identify weed types that commonly occurs in the coffee farm and provide recommendation for controlling mechanisms (i.e. cultural and chemical controlling) which helps to minimize crop loss.

4.6. Hardware/Software Mapping

One of the major tasks in system design is hardware/software mapping. This helps to identify which component would be a part in which hardware and soon. Generally, it shows the relation between the hardware and software in the system.

The system has two nodes such as the **Web server** and **Clients.** These nodes are shown as UML Deployment diagrams shown in Figure 4.3. The nodes represent specific instances (workstations) or a class of computers (web server).

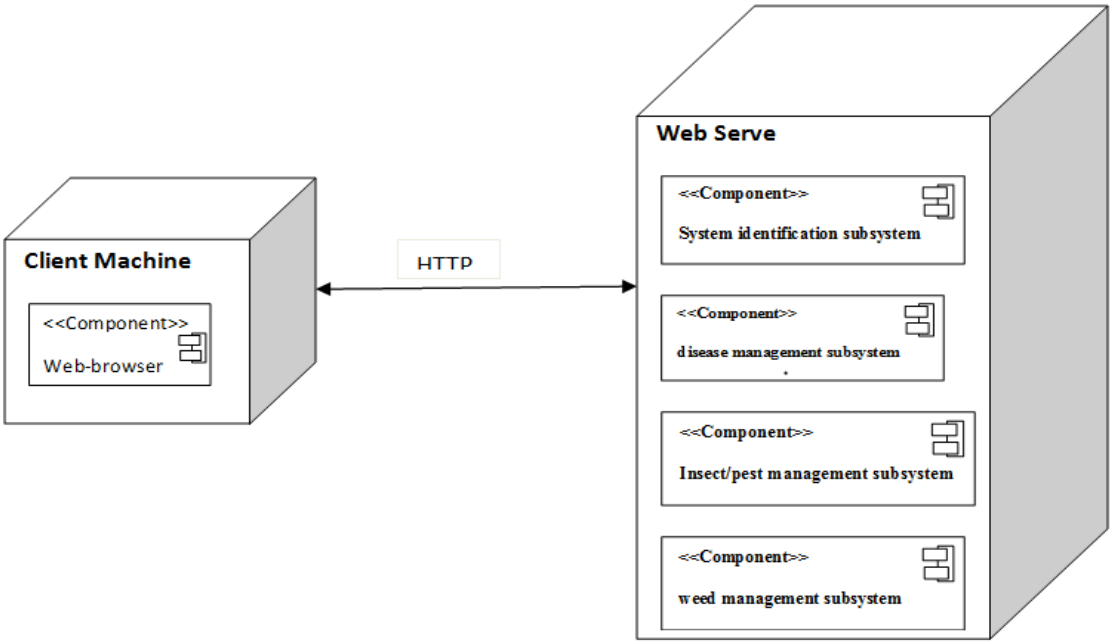

Figure 4.3 Deployment diagram

In the above figure, the user inserts the URL of the system on the client node using web browser (Mozilla or explorer) the request communicates with web server(apache) where the system stored then the server responds the results to the user(i.e. The home page of the system is displayed).

Chapter Five

Implementation

This chapter is about implementation of coffee expert system. The sub-topics, which will be discussed in this chapter, are: knowledge representation, the programming tools and the developed prototype of the system.

1.1 Knowledge Representation

The acquired data are represented in the knowledge base as a rule in rule-based expert system. The rules are defined by the key word '**RULE**' with some description about it in square bracket. Then the rule premises with the key word' **If** ',the logical expression consists of an attribute name, relational operators and comparison operators.The rule consequent is represented with '**Then'** key word. The following example shows knowledge representation of the system.

Example:

REM: Insect identification in dry condition

RULE [GCS]

If [status]=true and

[condition]="dry" and

[afected part]="coffee-leaves"and

[symptom]:"yellowing leaves""honey-dew and ants that eats it"

and

[color]="yes"

Then [the diagnosis]="Green-coffee-scale" and

REM: Disease identification

RULE [CBD]

If [obserb]=true and

[condition] = "humid" and
[affected-part] = "coffee-berries" and
[patch lesion] = true and
[patch lesion color]="pale pink in humid to brown-blight
during dry-hot" and
[symptom-affeted-parts] = "dark-brown berries"and
[other-symptom1]:"brown lesions on flower petals""dark-brown
berries"
Then [The diagnosis] = "Coffee Berry Disease(CBD)" and
[couse]="fungus(Colletotrichum kahawae)"

1.2 Prototype

In this section we describe, how the user interacts with the system by showing some of the interaction results with screen shots. When the user starts the application by inserting the "URL"(http://localhost/experts/home.html) the home page of the system is open as shown in Figure 5.1. The user then selects advice category. At this time, the subsystem identification knowledgebase is loaded with prompts and rules to determine whether the "pest management", "Disease management" or "weed management" subsystem to be active (refer Figure 5.2). Based on the users selection appropriate subsystem knowledgebase is loaded and interaction is continue to reach in to the goal.

The expert system has four knowledgebase. The first one is subsystem identification knowledgebase with Meta rules and prompts are used to determine the next knowledgebase to be loaded. The remaining KB: Pest knowledgebase, Disease knowledgebase and weed management knowledgebase with rules and prompts are used for identification of appropriate recommendation.

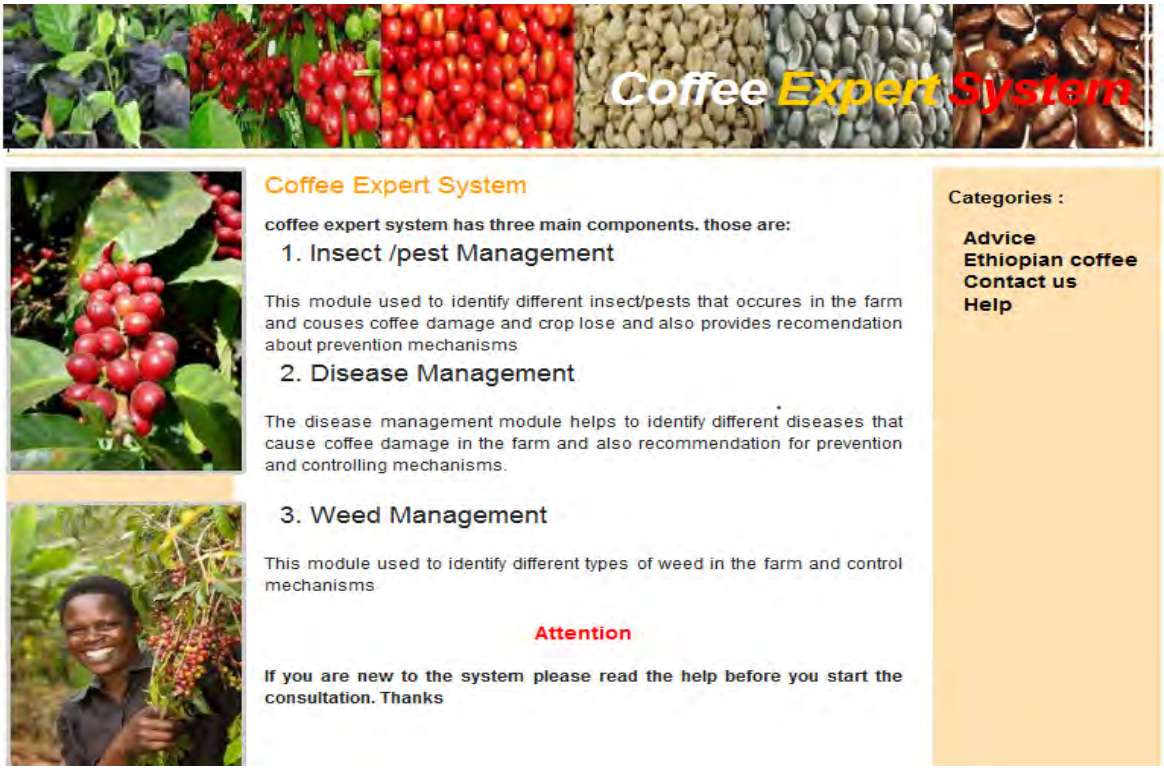

Figure 5.1 Home page of the system

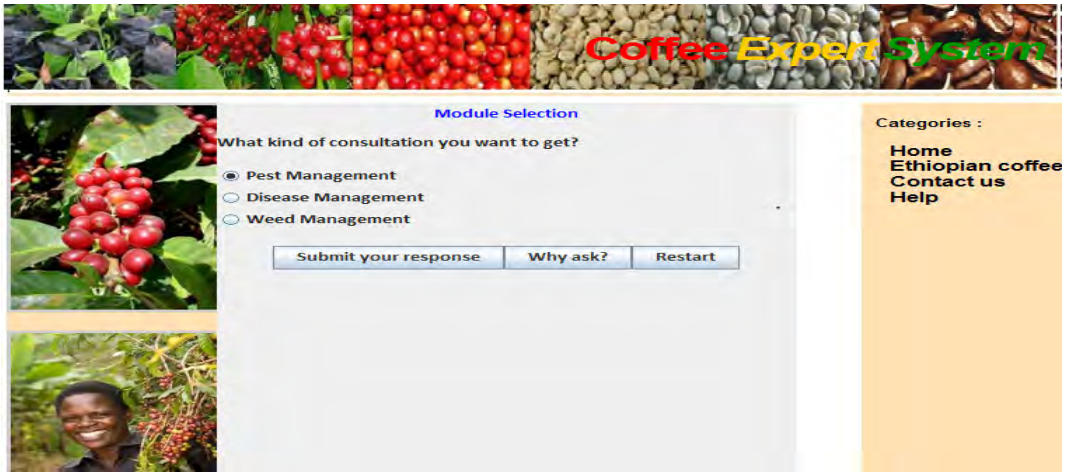

Figure 5.2 Subsystem selection page

The following discussion shows a scenario how the system proceeds.

If the user clicks on pest identification option and clicks submit button from the previous figure, the system will prompt sequence of questions to determine the type of pest that occur in the farm .The following figures show questions and users response and final answer for specific cases. Figure 5.3 will be displayed to ask a user if there is a pest in the field or not to continue consultation.

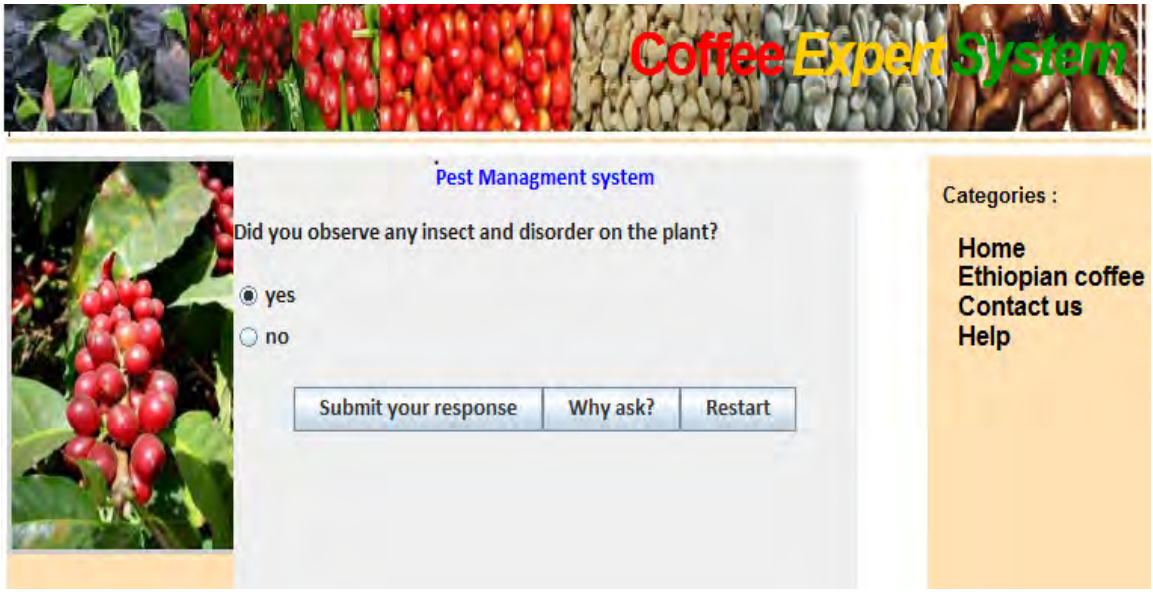

Figure 5.3 pest identification page

If the user selects yes option and submit the response, the following page will be displayed to ask user at which condition this insect damage and production rate increase as shown in figure 5.4

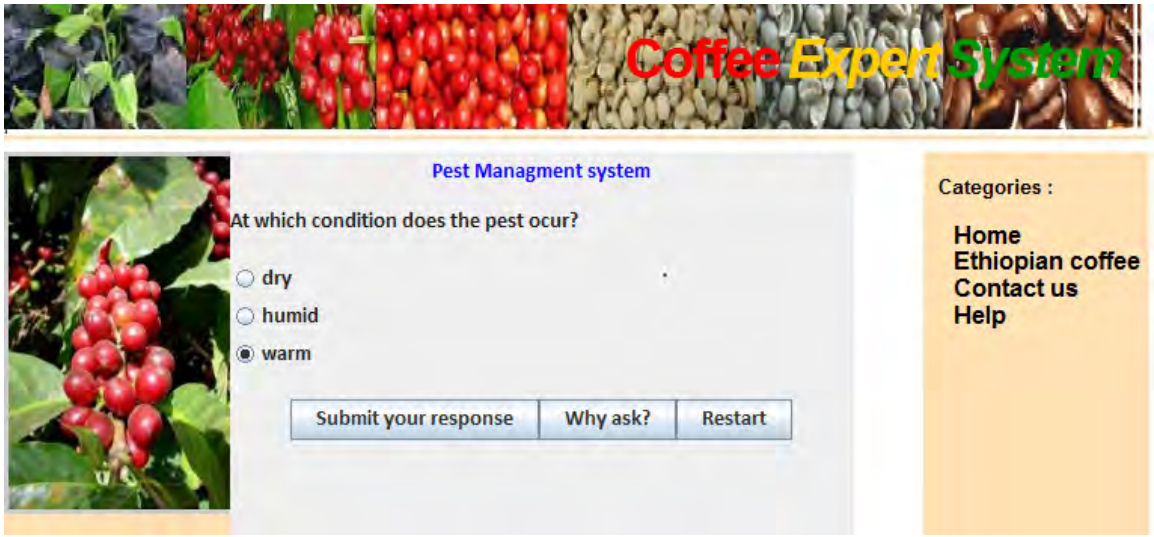

Figure 5.4 weather condition determination page

Then the system asks which part of the plant is affected at this condition show in figure 5.5

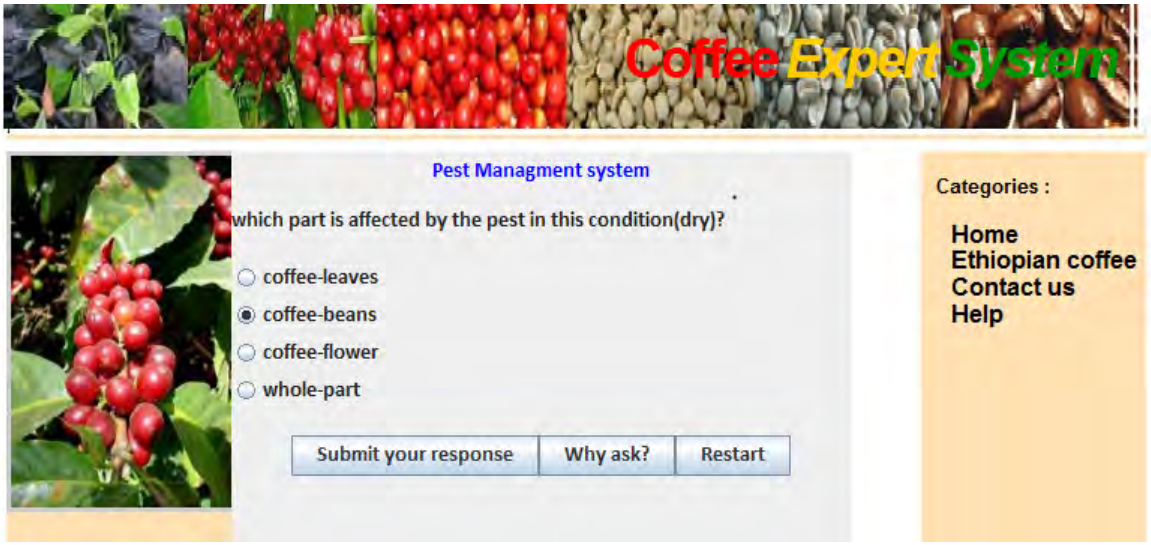

Figure 5.5 affected part selection page

When the user selects one option say (Coffee-beans) and submits response, the system display a prompt to know symptoms shown on affected part as shown in figure 5.6

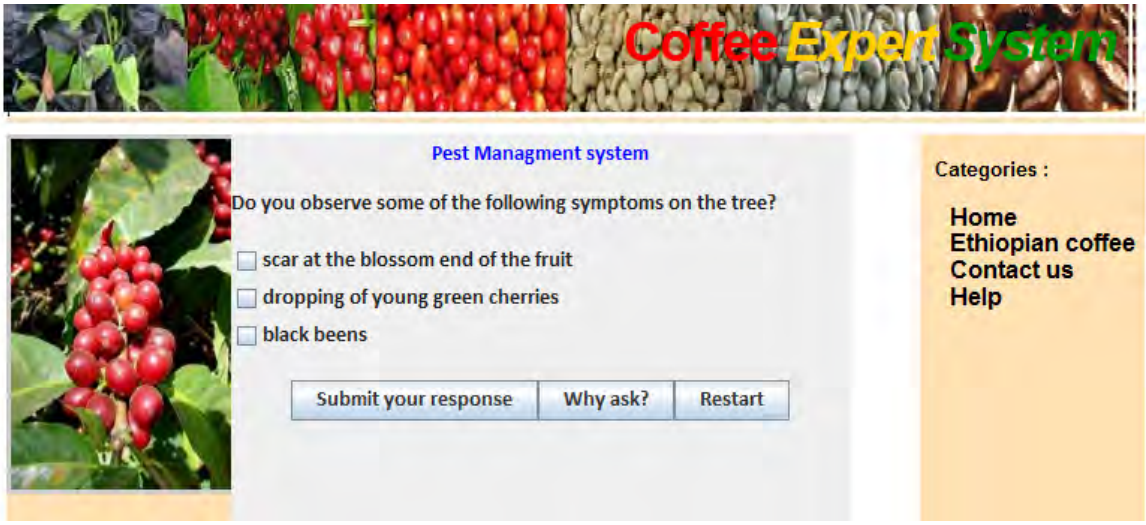

Figure 5.6 symptom selection page

When the user selects some of the symptoms that observe in the field at list one symptom and submit response the system displays a page that asks the pest color as shown in figure 5.7

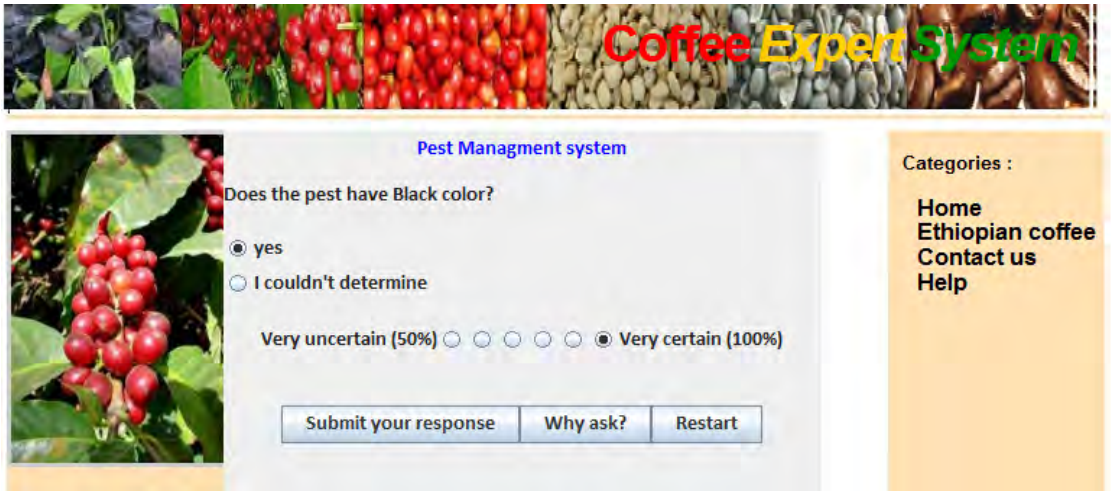

Figure 5.7 pest color identification page

When the user selects one of the options with some confidence value the system will provide the diagnosis result (the pest name and prevention mechanisms) as shown in figure 5.8

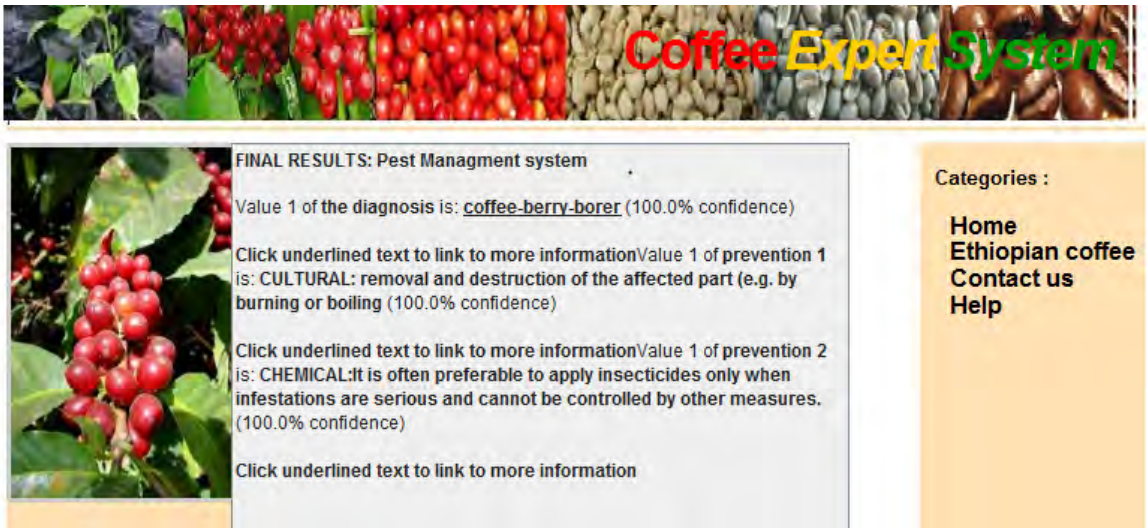

Figure 5.8 identified insect/pest page

If the user wants to see detail information about the identified insect/pest by clicking the underlined insect/pest name .then the detail description displayed as shown in figure 5.9

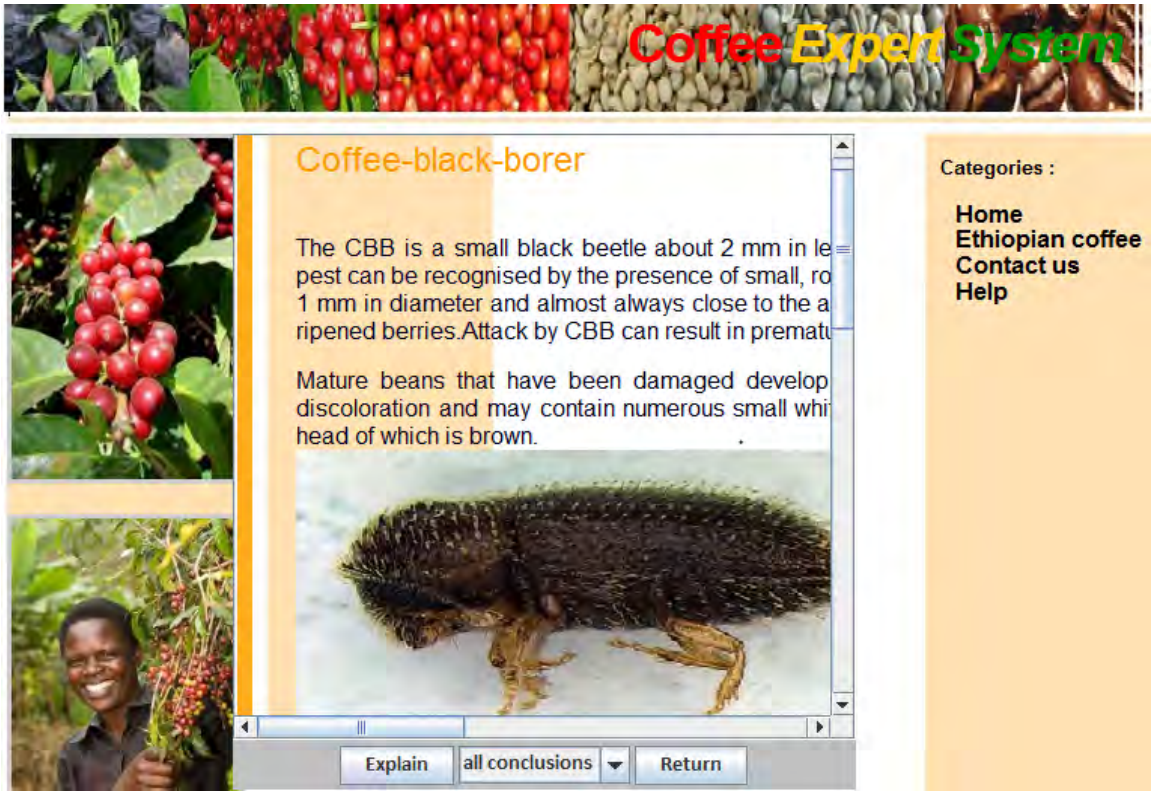

Figure 5.9 detail description of identified pest page

When we consult the system, we see different buttons like restart, return, explain and why ask.
While the “Restart” button is clicked at any step, the systems control reloads the subsystem identification knowledgebase.
When the user clicks “Explain” button at the end, the user can see the detail explanation of recommendation.
When the user clicks “why ask “button, the system explains the goal of the system. The other one is return button, when the user clicks on ”Return” button, at which pest detail is displayed , the system control transfers to the page where the identified pest is displayed.
For other subsystems follow the same procedures.

1.3 User uncertainty

While responding the prompts, the user might not be sure about his/her response, so the system should provide users to represent their degree of confidence to the response. They are given an option to enter their certainty to the response which ranges from 50% to 100%. If the user omits certainty value, the system takes the default 100%.

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Chapter six

System Evaluation

Expert system evaluation is the process of determining the quality of the system and advice it provides by using some evaluation criteria.

Even if there are no standardized criteria that we follow to evaluate, we use some common criteria to evaluate the system such as usability, impact of the system on users' decision, quality of information and usefulness of the system. Based on these criteria we prepared questionnaires (see appendix: D).

To evaluate the system, one domain expert and two crop production students are participated. For each respondent a questioner is given and they give a ranked value to all questions based on the evaluation category (see appendix D).

From the evaluation analysis, we can conclude that the evaluators agreed that the system satisfies the criteria's. When we see the overall analysis, the system is acceptable. For evaluation result (see appendix: E).

Chapter Seven

Conclusion and future work

7.1 Conclusion

This paper presents the use of expert systems in the agricultural domain and their importance as tools for information transfer through information generation from knowledge and expertise. It is proven that expert systems in agriculture helps a lot in increasing the crop production in many countries by disseminate expertise knowledge.

However, in Ethiopia there is no mechanism that helps to transfer and disseminate expertise knowledge to users except through experts and documents, but not easily available. Therefore, there should be a mechanism to make assistance available to user at any time. This project work is about development of Web-Based expert system for identification of Disease and pest and makes the necessary recommendation for prevention in Ethiopian coffee.

This system will help users especially extension workers who serves as a mediator between farmers and experts to control the problems in the farm by providing immediate expertise advice The knowledge has been acquired from experts and literatures and modeled into three modules: pest management, disease management and weed management. The system developed using rule-based expert system shell (e2gRuleEngine**)**. The evaluation analysis result of the system shows the system is acceptable.

7.2 Future Works

In order to improve the quality of the system and make it easy to use for everyone at anywhere, the following points should be considered

- The system concerns only for insect/disease diagnosis for plantation stage, it is better to give advice for all process from land preparation to coffee harvesting and processing
- Preparing the system using local language
- To make accessible for everyone any where make it mobile application

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Appendix

A: Factor table for insect pest

Name		Weather condition	Affected part	Color of the pest	Symptom on the affected part	Other symptoms
common	scientific					
WSB	*Monochamus leuconotus*	humid	steam	Grey with dark brown mark	1cm d hole on the steam rings on the stem	-Yellowing of leaves -wood shavings on ground
Leaf miners	Leucoptera caffeine washbourn	Warm	leaf	white	Leaf epidermis is yellow	-transparent area on leaf
Green coffee scale	*Coccus alpinus*	Dry	leaf	green	Leaf are yellowing	-honey-dew -ants black, soot-like coating on coffee leaves
Black twig Borer	Apate indistinctus	warm	Sunny-side -team	black	Circular hole(0.8mm)	-Yellowing of leaf -wilting of branch tips
CBB	*Hypothenemus hampei*	Dry	Berries(beans)	Black beetle	scar at the blossom end of the fruit	-fruit drop of young -green cherries -black beans
Coffee thrips	Diarthrothrips coffeae williams	Dry	Coffee flower	Grayish-brown	Flower abortion	-defoliation -crop loss

Coffee blotch miner	Leucoptera meyricki	humid	leaf	White moth	Leaf brownish	Leaf damage Spot or ¾ part of the leaf is brown
Mealy bugs	*Planococcus citri (p. citri)*	dry	Root,steam ,leaves, Fruit(whole -part)	White wax	Honey-dew,dwarfing,fungal growth	-Yellow leaf &wilt -ants
Antestia bug	Antestiopsis spp.	humid	Green-berries	Dark-brown/white/orange marking	Blacking of flowers & flower bud	-fall of immature berries -shortening of internodes -shrinks fruit

B: Disease factor table

Disease Types	Prevention Methods	
	Cultural	Scientific
Disease Name: Coffee Leaf Rust(CLR) Coues: fungus (hemileia vastafrix) Symptoms: -yellow/orange powder on leaf : -light coffee beans -patch on upper side -premature shedding of leaves. Affected part: leaf Condition :humid	Cultural practices can have an indirect but beneficial effect in terms of CLR control. For example, wider spacing and appropriate pruning help by preventing prolonged wetness and increasing penetration of fungicides sprayed into the tree canopy.	Fungicides are widely used for control of CLR. The timing of fungicide application is critical for controlling CLR, with maximum effect being achieved through application before the start and during the early period of the rainy season.
Disease Name: Coffee Berry Disease(CBD) Coues: fungus(*Colletotrichum kahawae*) Symptoms: -water-soaked lesions on berries -dark-brown berries -pale pink spores on lesions in humid. -brown-blight during dry and hot -brown lesions on flower petals Affected part: berry Condition: humid	Cultural management practices can indirectly control CBD. Providing wider spacing and ensuring that trees are pruned appropriately helps to prevent prolonged wetness and high relative humidity following periods of rainfall (conditions that are ideal for CBD development).	A number of fungicides are available for controlling CBD, but the use of chemicals is costly. Copper based fungicides are relatively cheap, very effective against CBD and also give protection against coffee leaf rust. The most economical approach is to use a tank mixture containing half the normal rate of copper fungicide (5 kg of 50% WP copper oxychloride) and half the normal rate of organic fungicide (2 kg chlorothalonil 75% WP).

Disease Name: Coffee Wilt Disease(CWD) Coues: fungus(*Fusarium xylarioides)* Symptoms: -Yellowing, folding and inward curling of the leaves -Leafless tree -Black-brown branches -berries ripen early Affected part: tree branches Condition: dry	On farms where CWD is already present, affected trees provide focal points for further infection and should be uprooted and burnt. Trees adjacent to affected trees should also be uprooted and burnt even if they appear healthy since they may already be infected by the fungus.	Chemical control is unlikely to be effective as the pathogen is known to live in the soil or inside the plant, making it hard to target even with systemic fungicides. Even if effective, the use of systemic fungicides would be costly and probably uneconomic, and would have undesirable environmental effects.
Disease Name: Coffee Bark Disease Coues: soil borne fungus(*Fusarium stilbioides)* Symptoms: -brown steam base branch -branches eventually breaks -yellowing of leaf Affected part: steams Condition: hot-dry	The most appropriate approach is to prevent introduction of the disease and, should it become present, to prevent or restrict on-farm spread a gap between trees.	The most appropriate approach is to prevent introduction of the disease
Disease Name: Brown Eye Spot disease		

Coues: fungus(*Cercospora coffeicola)* Symptoms: -chlorotic spots on the leaves -circular or perhaps angular spot -dark brown, patch lesions on the coffee berries, -red spots on green and ripening berries Affected part: leaf, berries Condition : warm- humid	Control of brown eye spot is not usually necessary for mature *C. arabica* plants.	-
Disease Name: Bacterial Blight Coues: bacteria Symptoms: -pale green spot(water-soaked) on leaf -Blackened tips of branch -brown and dry leaf -dried leaves remain attached -flowers and pin-heads are black Affected part: whole part Condition: wet-cold	Cut off infected twigs and branches. Plant shade trees and wind breaks on exposed sides of BBC areas. Observe field hygiene by disinfecting tools used for pruning infected trees with a suitable disinfectant such as Kerol 0.1 % , Lysol 3%. Avoid planting materials from known BBC areas.	Critical spray time is just before, during and after flowering especially when these coincide with wet weather. Complete first spray by mid-February and continue through the rains at two week intervals and after rains at three week interval

C: weed factor table

Weed type	Characteristics	Growing nature	Control mechanism	
			Cultural	Chemical
Grass	-tabular and joint steam -round,hollow flower steam -long narrow leaves -leaves aligned in two rows on steam	Perennial (for more than one season	1. Proper soil tillage, fertilizer, and water management 2.Mulching 3.Green manuring 4.Intercropping 5.Field sanitation 6.Crop rotation	Herbicides are essential for controlling weeds but their use need to be minimized to meet the demands. glyphosate is used to control the grass at various growth stage.
Sedges(grass-like)	-solid and jointless triangular steam -solid,3-angled flower steam -narrow leaves in three vertical rows -non-showy flower heads	Perennial	The same cultural practices are performed like grass weed control	Herbicides are essential for controlling weeds but thier use need to be minimized to meet the demands. glyphosate is used to control the grass at various growth stage.
Broad-leaves	-broad leaves -networked veins on the leave	Perennial	The easiest and most effective way to control perennials is to prevent their establishment.	Only a few herbicides effectively control perennial weeds. The three herbicides available for use in field crops are 2,4-D, Banvel and Roundup
		Annual (one season)	Implementing proper fertilization, mowing and irrigation practices during the summer months will lead to the development of a healthy, dense turfgrass stand in the fall.	Preemergence:Isoxaben (Gallery™ 75DF) herbicide must be applied prior to the germination of weed seed and applied at rates of 0.66-1.33 lbs product per. The other is Postemergence:use of herbicides

D: System Evaluation questionnaires

Objective:

The objective of this questioner is to collect data from user evaluation of coffee expert system.

Instruction: please use the (✓) to your answer for each question.

Value	score
Strongly disagree	1
disagree	2
Neutral	3
Agree	4
Strongly agree	5

System evaluation questioners

Evaluation Questions		Score				
		1	2	3	4	5
1	User interface design has consistent look and attractive					
2	The system is easy to use					
3	Instructions are easy to understand					
4	The system enables user to take decision and provide advice					
5	The system provides appropriate explanation for users (why and how)question					

6	The system will increase users confidence and performance					
7	The system is complete enough to provide intended advice					
8	The system responses is quick					
9	The decision is correct compared to experts					
10	The system can be used as tool to transfer experts knowledge					
11	Navigations are easy to use.					
12	The system helps users to save time					

E: Evaluation Result

Q.No	Question	Score					Total	Average
1	User interface design has consistent look and attractive	1	2	3	4	5	15	5
						3		
2	The system is easy to use					3	15	5
3	Instructions are easy to understand					3	15	5
4	The system enables user to take decision and provide advice				1	2	14	4.6
5	The system provides appropriate explanation for users (why and ow)question				2	1	13	4.3
6	The system will increase users confidence and performance				1	2	14	4.6
7	The system is complete enough to provide intended advice				3		12	4
8	The system responses is quick				3		12	4
9	The decision is correct compared to experts				3		12	4
10	The system can be used as tool to transfer experts knowledge				1	2	14	4.6
11	Navigations are easy to use.					3	15	5
12	The system helps users to save time					3	15	5
Final analysis result								**4.59**

F: Rules of Coffee expert System

Subsystem Identification knowledgebase

```
REM linked knowledge bases: this is the root knowledge base


Rule [Pest subsystem metarule]
If [consultation] = "Pest Management"
Then [nextKB] = "Pests1.txt" and
[nextAppTitle] = "Pest Managment system" and
[nextBGColor] = "#EFEFEF" and
[nextPColor] = "#232323" and
[nextTColor] = "#0000FF"


Rule [disease subsystem metarule]
If [consultation] = "Disease Management"
Then [nextKB] = "disease.txt" and
[nextAppTitle] = "Disease Managment system" and
[nextBGColor] = "#EFEFEF" and
[nextPColor] = "#232323" and
[nextTColor] = "#0000FF"


Rule [weed subsystem metarule]
If [consultation] = "Weed Management"
Then [nextKB] = "weed.txt" and
```

[nextAppTitle] = "Weed Managment system" and

[nextBGColor] = "#EFEFEF" and

[nextPColor] = "#232323" and

[nextTColor] = "#0000FF"

PROMPT [consultation] ForcedChoice

"What kind of consultation you want to get?"

"Pest Management"

"Disease Management"

"Weed Management"

GOAL [nextKB]

MINCF 80

2, pest knowledgebase

```
REM pest identification knowledgebase
RULE [B]
If [status]="no"
   Then [the diagnosis]="If there is disorder but no insect/pest please select disease
management"and
     [prevention 1]="since value is not determine no prevention"and
     [prevention 2]="same"
RULE [GCS]
If [status]="yes" and
  [condition]="dry" and
  [afected part]="coffee-leaves"and
  [symptom]:"yellowing leaves""honey-dew and ants that eats it" and
  [color]="yes"
   Then [the diagnosis]="Green-coffee-scale" and
       [prevention 1]="CULTURAL: Provided with optimum nutrition (mulch, fertilizer and well
rotted manure) to maximize growth, vigour and resistance to attack by scale and to minimize
damage and yield loss."and
       [prevention 2]="CHEMICAL:Various oils, including refined white oils, and soap solutions
are used to control scale infestations."
RULE [GCS1]
If [status]="yes" and
  [condition]="dry" and
```

[afected part]="coffee-leaves"and

[symptom]:"yellowing leaves""honey-dew and ants that eats it" and

[color]="I couldn't determine"

Then [the diagnosis]="Green-coffee-scale" and

[prevention 1]="CULTURAL: Provided with optimum nutrition (mulch, fertilizer and well rotted manure) to maximize growth, vigour and resistance to attack by scale and to minimize damage and yield loss."and

[prevention 2]="CHEMICAL:Various oils, including refined white oils, and soap solutions are used to control scale infestations."

RULE [CBB]

If [status]="yes" and

[condition]="dry" and

[afected part]="coffee-beans"and

[symptom1]:"scar at the blossom end of the fruit""dropping of young green cherries""black beens" and

[color1]="yes"

Then [the diagnosis]="coffee-berry-borer" and

[prevention 1]="CULTURAL: removal and destruction of the affected part (e.g. by burning or boiling" and

[prevention 2]="CHEMICAL:It is often preferable to apply insecticides only when infestations are serious and cannot be controlled by other measures."and

[recomend]="prevention"

RULE [CBB1]

If [status]="yes" and

[condition]="dry" and

[afected part]="coffee-beans"and

[symptom1]:"scar at the blossom end of the fruit""dropping of young green cherries""black beens" and

[color1]="I couldn't determine"

Then [the diagnosis]="coffee-berry-borer" and

[prevention 1]="CULTURAL: removal and destruction of the affected part (e.g. by burning or boiling" and

[prevention 2]="CHEMICAL:It is often preferable to apply insecticides only when infestations are serious and cannot be controlled by other measures."

RULE [CT1]

If [status]="yes" and

[condition]="dry" and

[afected part]="coffee-flower"and

[symptom2]:"Flower abortion""Tree defoliation crop loss" and

[color2]="I couldn't determine"

Then [the diagnosis]="Coffee-thrips" and

[prevention 1]="CULTURAL: Mulching, pruning and irrigation reduce thrips population" and

[prevention 2]="CHEMICAL:Several chemicals are recommended. Spray Dicrotophos 40%M.l..at 700mls/ha has good result"

RULE [CT]

If [status]="yes" and

[condition]="dry" and

[afected part]="coffee-flower"and

[symptom2]:"Flower abortion""Tree defoliation crop loss" and

[color2]="yes"

Then [the diagnosis]="Coffee-thrips" and

[prevention 1]="CULTURAL: Mulching, pruning and irrigation reduce thrips population" and

[prevention 2]="CHEMICAL:Several chemicals are recommended. Spray Dicrotophos 40%M.l..at 700mls/ha has good result"

RULE [MB]

If [status]="yes" and

[condition]="dry" and

[afected part]="whole-part"and

[symptom3]:"Yellowing and wilting of leaves ""honey-dew and ants that eats it""dwarfing of tree" and

[color3]="yes"

Then [the diagnosis]="Mealy-bugs" and

[prevention 1]="CULTURAL: Provided adequate nutrition in the form of fertilizer, mulch or well-rotted manure to enhance growth and vigour. If the tree is affected , uprooting and burning is preferable to destroy the insects and helps to prevent further spread " and

[prevention 2]="CHEMICAL:Chemical control is not easy due to the root mealy bug being present on the roots of the plant and the presence of the protective wax and the fungal layer.

pesticide such as Furadan (carbofuran), Dursban chlorpyrifos) or Mashal (carbosulfan) 10% granules applied at a rate of 10 g per tree, and the soil replaced. effective if applied during the early stages of attack."

RULE [MB]

If [status]="yes" and

[condition]="dry" and

[afected part]="whole-part"and

[symptom3]:"Yellowing and wilting of leaves ""honey-dew and ants that eats it""dwarfing of tree" and

[color3]="I couldn't determine"

Then [the diagnosis]="Mealy-bugs" and

[prevention 1]="CULTURAL: Provided adequate nutrition in the form of fertilizer, mulch or well-rotted manure to enhance growth and vigour. If the tree is affected , uprooting and burning is preferable to destroy the insects and helps to prevent further spread " and

[prevention 2]="CHEMICAL:Chemical control is not easy due to the root mealy bug being present on the roots of the plant and the presence of the protective wax and the fungal layer. pesticide such as Furadan (carbofuran), Dursban chlorpyrifos) or Mashal (carbosulfan) 10% granules applied at a rate of 10 g per tree, and the soil replaced. effective if applied during the early stages of attack."

RULE [AB]

If [status]="yes" and

[condition]="humid" and

[afected part1]="Green-berries"and

[symptom4]:"Blacking of flowers and flower bud""Fall of immature berries and shirinking""Shortening of internodes" and

[color4]="I couldn't determine"

Then [the diagnosis]="Antestia-bug" and

[prevention 1]="CULTURAL: Pruning of coffee trees and shade tree regulation can reduce Antestia populations by producing unfavorable temperature and humidity condition." and

[prevention 2]="CHEMICAL:Chemical Spraying should be done when the average population of Antestia reaches more than 5/tree."

RULE [AB1]

If [status]="yes" and

[condition]="humid" and

[afected part1]="Green-berries"and

[symptom4]:"Blacking of flowers and flower bud""Fall of immature berries and shirinking""Shortening of internodes" and

[color4]="yes"

Then [the diagnosis]="Antestia-bug" and

[prevention 1]="CULTURAL: Pruning of coffee trees and shade tree regulation can reduce Antestia populations by producing unfavorable temperature and humidity condition." and

[prevention 2]="CHEMICAL:Chemical Spraying should be done when the average population of Antestia reaches more than 5/tree."

RULE [CL1]

If [status]="yes" and

[condition]="humid" and

[afected part1]="coffee-leaves"and

[symptom5]:"Spot or ¾ part of the leaf is brown ""Leave damages" and

[color5]="I couldn't determine"

Then [the diagnosis]="Coffee-blotch-miner" and

[prevention 1]="CULTURAL: pruning of coffee and moderate shading is important ." and

[prevention 2]="CHEMICAL: controlled by insecticides, unfortunately this often leads to secondary outbreaks"

RULE [CL]

If [status]="yes" and

[condition]="humid" and

[afected part1]="coffee-leaves"and

[symptom5]:"Spot or ¾ part of the leaf is brown ""Leave damages" and

[color5]="yes"

Then [the diagnosis]="Coffee-blotch-miner" and

[prevention 1]="CULTURAL: pruning of coffee and moderate shading is important ." and

[prevention 2]="CHEMICAL: controlled by insecticides, unfortunately this often leads to secondary outbreaks"RULE [WSB]

If [status]="yes" and

[condition]="humid" and

[afected part1]="coffee-steam"and

[symptom6]:"Around 1cm d hole on the steam ""Yellowing of leaves""wood shavings on ground" and

[color6]="yes"

Then [the diagnosis]="White-coffee-steam-borer" and

[prevention 1]="CULTURAL: providing adequate nutrition. This reduces the likelihood of attack, helps to minimise levels of infestation and also reduces the extent of damage." and

[prevention 2]="CHEMICAL:applying insecticides such as Regent® 200SC (Fipronil) to the surface of the lower 0.5 metres2 of the main stem with a brush"

RULE [WSB1]

If [status]="yes" and

[condition]="humid" and

[afected part1]="coffee-steam"and

[symptom6]:"Around 1cm d hole on the steam ""Yellowing of leaves""wood shavings on ground" and

[color6]="I couldn't determine"

Then [the diagnosis]="White-coffee-steam-borer" and

[prevention 1]="CULTURAL: providing adequate nutrition. This reduces the likelihood of attack, helps to minimise levels of infestation and also reduces the extent of damage. ." and

[prevention 2]="CHEMICAL:applying insecticides such as Regent® 200SC (Fipronil) to the surface of the lower 0.5 metres2 of the main stem with a brush"

RULE [BB]

If [status]="yes" and

[condition]="warm" and

[afected part2]="coffee-steam"and

[symptom7]:"Circular hole(around 0.8mm) on the steam ""Yellowing of leaf""wilting of branch tips" and

[color7]="yes"

Then [the diagnosis]="Black-Borer " and

[prevention 1]="CULTURAL:Pruning and destruction of beetle-infested plant material is highly recommended. Simultaneously, apply good tree care practices to promote tree vigor and health to aid in recovery from beetle damage." and

[prevention 2]="CHEMICAL:If an insecticide is warranted, check for phytotoxicity prior to application by spraying one or two branches and follow label directions carefully"

RULE [BB1]

If [status]="yes" and

[condition]="warm" and

[afected part2]="coffee-steam"and

[symptom7]:"Circular hole(around 0.8mm) on the steam ""Yellowing of leaf""wilting of branch tips" and

[color7]="I couldn't determine"

Then [the diagnosis]="Black-Borer " and

[prevention 1]="CULTURAL: Pruning and destruction of beetle-infested plant material is highly recommended. Simultaneously, apply good tree care practices to promote tree vigor and health to aid in recovery from beetle damage. " and

[prevention 2]="CHEMICAL:. If an insecticide is warranted, check for phytotoxicity prior to application by spraying one or two branches and follow label directions carefully"

RULE [LM]

If [status]="yes" and

[condition]="warm" and

[afected part2]="coffee-leaves"and

[symptom8]:"Leaf epidermis is yellow ""transparent area on leaf" and

[color8]="yes"

Then [the diagnosis]="Leaf miners" and

[prevention 1]="CULTURAL: Pruning of coffee and moderate shading is important" and

[prevention 2]="CHEMICAL:Use of chemicals are recommended when an average of 35 moths/mature tree is observed"

RULE [LM1]

If [status]="yes" and

[condition]="warm" and

[afected part2]="coffee-leaves"and

[symptom8]:"Leaf epidermis is yellow ""transparent area on leaf" and

[color8]="I couldn't determine"

Then [the diagnosis]="Leaf miners" and

[prevention 1]="CULTURAL: Pruning of coffee and moderate shading is important" and

[prevention 2]="CHEMICAL:Use of chemicals are recommended when an average of 35 moths/mature tree is observed"

PROMPT [status] ForcedChoice

"Did you observe any insect and disorder on the plant?"

"yes"

"no"

PROMPT [condition] ForcedChoice

"At which condition does the pest ocur?"

"dry"

"humid"

"warm"

PROMPT [afected part] ForcedChoice

"which part is affected by the pest in this condition(dry)?"

"coffee-leaves"

"coffee-beans"

"coffee-flower"

"whole-part"

PROMPT [afected part1] ForcedChoice

"which part is affected by the pest?"

"Green-berries"

"coffee-leaves"

"coffee-steam"

PROMPT [afected part2] ForcedChoice

"which part is affected by the pest?"

"coffee-leaves"

"coffee-steam"

PROMPT [color] ForcedChoice CF

"Does the pest have Green color?"

"yes"

"I couldn't determine"

PROMPT [color7] ForcedChoice CF

"Does the pest have Black color?"

"yes"

"I couldn't determine"

PROMPT [color8] ForcedChoice CF

"Does the pest have white color?"

"yes"

"I couldn't determine"

PROMPT [color4] ForcedChoice CF

"Does the pest have Dark-brown/white/orange marking color?"

"yes"

"I couldn't determine"

PROMPT [color5] ForcedChoice CF

"Does the pest have White moth color?"

"yes"

"I couldn't determine"

PROMPT [color1] ForcedChoice CF

"Does the pest have Black color?"

"yes"

"I couldn't determine"

PROMPT [color2] ForcedChoice CF

"Does the pest have Grayish-brown color?"

"yes"

"I couldn't determine"

PROMPT [color3] ForcedChoice CF

"Does the pest have Grayish-brown color?"

"yes"

"I couldn't determine"

PROMPT [color6] ForcedChoice CF

"Does the pest have Grey with dark brown mark color?"

"yes"

"I couldn't determine"

PROMPT [symptom] AllChoice

"Do you observe some of the following symptoms on the tree?"

"yellowing leaves"

"honey-dew and ants that eats it"

PROMPT [symptom1] AllChoice

"Do you observe some of the following symptoms on the tree?"

"scar at the blossom end of the fruit"

"dropping of young green cherries"

"black beens"

PROMPT [symptom4] AllChoice

"Do you observe some of the following symptoms on the tree?"

"Blacking of flowers and flower bud"

"Fall of immature berries and shirinking"

"Shortening of internodes"

PROMPT [symptom2] AllChoice

"Do you observe some of the following symptoms on the tree?"

"Flower abortion"

"Tree defoliation crop loss"

PROMPT [symptom5] AllChoice

"Do you observe some of the following symptoms on the tree?"

"Spot or ¾ part of the leaf is brown "

"Leave damages"

PROMPT [symptom6] AllChoice

"Do you observe some of the following symptoms on the tree?"

"Around 1cm d hole on the steam "

"Yellowing of leaves"

"wood shavings on ground"

PROMPT [symptom3] AllChoice

"Do you observe some of the following symptoms on the tree?"

"Yellowing and wilting of leaves "

"honey-dew and ants that eats it"

"dwarfing of tree"

PROMPT [symptom7] AllChoice

"Do you observe some of the following symptoms on the tree?"

"Circular hole(around 0.8mm) on the steam "

"Yellowing of leaf"

"wilting of branch tips"

PROMPT [symptom8] AllChoice

"Do you observe some of the following symptoms on the tree?"

"Leaf epidermis is yellow "

"transparent area on leaf"

GOAL [the diagnosis]

GOAL [prevention 1]

GOAL [prevention 2]

REM link the goal to html page for more descripton

HYPERLINK [the diagnosis] = "coffee-berry-borer" "pest/bery.html"

HYPERLINK [the diagnosis] = "Green-coffee-scale" "pest/gren.html"

HYPERLINK [the diagnosis] = "White-coffee-steam-borer" "pest/wcs.html"

HYPERLINK [the diagnosis] = "Leaf miners" "pest/lml.html"

HYPERLINK [the diagnosis] = "Black-Borer " "pest/borer.html"

HYPERLINK [the diagnosis] = "Coffee-blotch-miner" "pest/lm.html"

HYPERLINK [the diagnosis] = "Antestia-bug" "pest/ab.html"

HYPERLINK [the diagnosis] ="Mealy-bugs" "pest/mb.html"

HYPERLINK [the diagnosis] = "Coffee-thrips" "pest/thrip.html"

REM minimum confidence factor

MINCF 80

Declaration

This project is my original work and has not been presented or submitted as a partial requirement for a degree in any other university.

Name: Ruth Gashaw Tafesse

Signature:_____

Date:_____

Confirmed by advisor:

Name: Sebsibe H/mariam (PhD)

Signature:_____

Date:_____

Place and date of submission: Addis Ababa, June 2011