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Development of Knowledge Based System for Wheat Disease Diagnosis: A Rule Based Approach

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***Abstract*—Wheat production in Ethiopia is widely affected by diseases and attacked by a number of insect pests. Wheat disease diagnosis needs sufficient and knowledgeable agricultural experts to identify the diseases and describe the methods of treatment and protection at early stage of infestation. But, agricultural specialist assistance may not always available and accessible to every farmer when the need arises for their help. Hence, this study presents a rule based knowledge based system for wheat disease diagnosis in order to identify wheat disease timely and apply the control measures effectively. The system aims to provide a guide for research centers and development agents to facilitate the diagnostic process. To develop the system, data and knowledge is acquired from documented and non- documented sources. The acquired knowledge is modeled using decision tree structure that represents concepts and procedures involved in the diagnosis of wheat disease. The system is developed using SWI Prolog programming language. The system has been tested and evaluated to ensure whether the performance of the system is accurate and the system is usable by research centers and development agents. The system has been registered the overall performance of 87.78%. So, the developed system has potential to use as a decision tool for diagnosing and treating wheat disease.**

Keywords—AI; agriculture; KBS; rule based reasoning; wheat disease

I. Introduction

Agriculture is the mainstay of the Ethiopian economy and the livelihoods of more than 80% of the citizens [1]. Ethiopia is the largest wheat producer in sub-Saharan Africa, next to South Africa and wheat is the second most important in total production next to maize and the third in area after maize and sorghum that plays a significant role in assuring food sufficiency [2]. Despite the expansion of wheat in most parts of Ethiopia, the country is not self-sufficient in production and consequently a large quantity of wheat is imported every year to fill the gap. The national average of wheat in the country, which is 14 qt/ha, is 24%, is still below the average of South Africa yield and 48% below that of the world's [3]. This low production & productivity is mainly due to diseases, frost drought, poor soil fertility, soil erosion, pests and problematic weeds [4].

According to Hailu [4], wheat production in Ethiopia is widely affected by diseases and pests. Such diseases and pests reduce yield, quality and marketability of the wheat crop. This problem needs sufficient and knowledgeable agricultural experts to identify the diseases and describe the methods of treatment and protection at early stage of infestation. Unluckily, agricultural specialist assistance may not always available and accessible to every farmer when the need arises for their help. Moreover, there is a shortage of extension agents to provide quick and timely decision making as each agent has to serve on average 1090 farmers [5].To address such problems the application of information technology is important to deploy in agricultural area. Knowledge based system is one aspect of information technology which provides the appropriate management for diagnosing diseases attacking crop [6][7]. Knowledge Based System (KBS) is computer program that replicate the reasoning processes of a human expert in order to deliver a solution concerning a problem [8].

Hence, this study presents the development of rule based knowledge based system for wheat disease diagnosis that can provide advice for research centers and development agents to facilitate the diagnostic process. KBS can act as an expert on demand without wasting time, anytime and anywhere. With the proper utilization of knowledge, the knowledge based systems make decisions, recommendations and perform tasks based on user input, increase productivity and document rare knowledge by capturing scarce expertise and enhances problem solving capabilities in most flexible way [8].

II. Related Works

There are many works in the literature that explains about knowledge based systems in the agriculture domain. Local research work shows that Berhanu[9] developed a knowledge based system for coffee disease diagnosis and treatment. The study was focused on the development of KBS for coffee disease and pest control where it is intended for the diagnosis of common diseases and pests occurring in the coffee plant. A knowledge based system for cereal crop diagnosis and treatment is explored by Ejigu [10]. The focus of the study was to address problems of common diseases occurring in cereal crop.

Moreover, internationally Hogeveen et al. [11] developed an integrated knowledge based system for dairy farms that serves diagnostic, problem solving, and advising role in controlling the health and production of a herd, including the financial consequences. King et al. [12] developed a knowledge based system for malting barley management. The system gives advice on fertilizer and water applications to maximize crop yield under strict quality constraints. Yelapure et al. [13] developed knowledge based system for tomato crop with special reference to pesticides. This system helps to identify the pests and to suggest pesticide treatment to control it.

To conclude, several studies have been developed in AI using knowledge based systems to reason out the solution of a particular problem. But, according to the researcher's knowledge, there are no research conducted to design a knowledge based system for wheat disease diagnosis and treatment. Thus, in this study an attempt is made to develop a rule based knowledge based system for wheat disease diagnosis and to test and evaluate its performance with the help of professional experts in the field.

Therefore, the proposed knowledge based system can assist domain experts during wheat disease diagnosis and treatments by providing advisory services. This work will also be used as an input for further disease diagnosing and management in agricultural industry.

III. METHODOLOGY OF THE STUDY

In this study, different procedures are followed in developing the proposed knowledge based system. These are: knowledge acquisition, knowledge modeling, knowledge Representation, Knowledge based system development for wheat disease diagnosis and Evaluation of the system.

The primary knowledge needed for this study is acquired from Debre zeit Agricultural research center. Four domain experts are selected using purposive sampling techniques and interviewed to extract the tacit knowledge. Similarly, documented sources of knowledge are consulted on the area of crop protection and treatment from different sources such as agricultural books, journals, publications, internet sources, plant disease protection guidelines and training manuals are analyzed.

The acquired knowledge is modeled using decision tree. Decision tree shows the relationships of the problem graphically and can handle complex situations in a compact form. Knowledge diagramming is often more natural to experts than formal representation methods and decision trees can easily be converted to rules. Decision tree is drawn using flow chart symbols as it is easier for many to read and understand. It helps to identify a strategy most likely to reach a goal and allow the addition of new scenarios

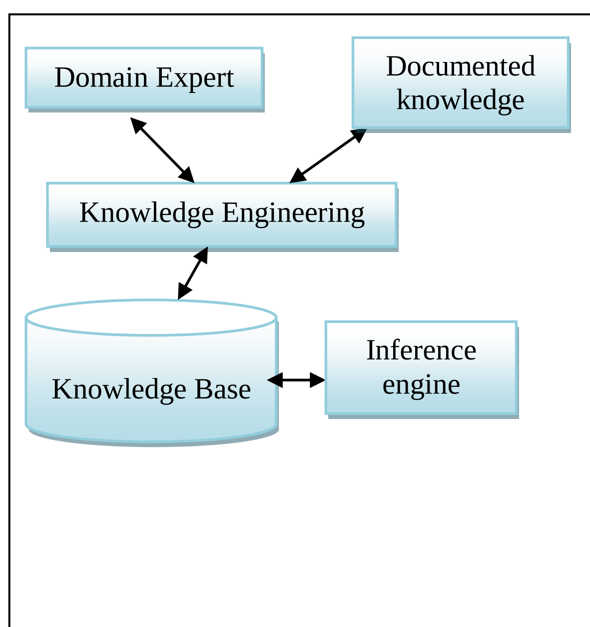
After modeling the acquired knowledge using decision tree, it is represented in a format that is both understandable by humans and executable on computers. Production rules are the most popular form of knowledge representation which is easy to understand and reasonably efficient in diagnosing problems. Knowledge is represented in the form of condition-action pairs: IF this condition (or premise or antecedent) occurs, THEN some action (or result or conclusion or consequence) will (or should) occur.

Prolog programming language is used to develop a rule based knowledge based system for wheat disease diagnosis. The reasons for selecting Prolog are the features and abilities of the language that incorporate it. Prolog is a declarative language and has the capacity to describe the real world. Because of its declarative semantics, built-in search, and pattern matching, Prolog provides an important tool for programs that process natural language.

To achieve the established objective of the study, the prototype system is extensively tested and evaluated to ensure that whether the performance of the system is accurate and the system is usable by research centers and development agents.

IV. MODEL DEVELOPMENT

Wheat disease diagnosis KBS is designed based on rule based reasoning techniques. As shown in figure1, the model shows that, the knowledge is acquired from experts and documented knowledge sources. Potential sources of knowledge include domain experts, books, journal articles, proceedings, electronic sources and information available on the web. Then the acquired knowledge is effectively coded in the knowledge base by knowledge engineer. Knowledge base contains rule base from which the system draws conclusion through inference engine. The inference engine accepts query from the user via user interface and prompt the action in user understandable form if the goal is satisfied. A backward chaining technique is used as inference mechanism to search and extract the rules for specific type of wheat disease.



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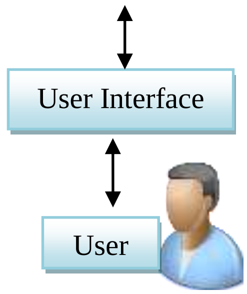

Figure 1. Architecture of the proposed system

V. PROPOSED SYSTEM USER INTERFACE

To interact with the system the user interface is needed. User interface is a bidirectional communication between the system and the user. It is the window through which the system is able to return information to the user.

Once the file 'WDDKBS.pl' is opened, the end-users can start wheat disease diagnosis by writing the word "advice" followed by full stop "." and the welcome window is displayed along with the menu containing choices as shown in figure2. Then the system requests end-users to choose the infected part of the wheat. If a choice match, the system asks the users a series of questions and the users respond by saying "yes" or "no". Based on the user's response, the system provides conclusions for the users request through the user interface .

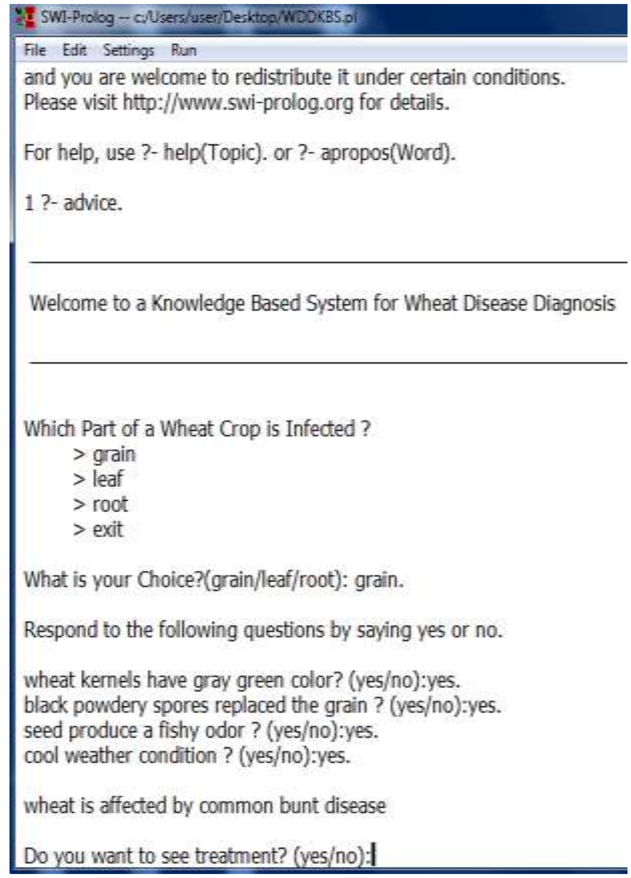

Figure 2. Sample dialogue of the proposed system during diagnosis

VI. SYSTEM TESTING AND EVALUATION

Once a proposed knowledge based system is developed, it should be tested and evaluated to measure its performance in diagnosing wheat diseases and determine whether the system satisfies the requirements of its users and applicable in the domain area. Testing and evaluation of the prototype system is the final step that can assist the knowledge engineer to measure, if the objective of the proposed system is met or not. To check if the system fits its purpose, system testing and user acceptance testing are used.

A. User Acceptance Testing

In this paper, user acceptance testing is undertaken to assess the performance of the system from domain experts' perspective and measure how well the system accomplished its tasks in the domain area. Researchers' prepared checklists for domain experts to make evaluations and comments while interacting with the system. Thus, six domain experts are selected purposively from Debre zeit agricultural research center. For user acceptance testing, questionnaires are customized from Adane[14].

Finally, all experts are requested to evaluate the system based on a given questionnaire. The evaluators are given questionnaires which are answered as **excellent, very good, good, fair and poor**. For those questionnaires, the evaluators are given their judgment as shown in Table 1. For the purpose of analysis, values for all attributes are given as **excellent = 5, very good = 4, good = 3, fair = 2 and poor = 1**. Based on the given scale, system evaluators provide a value for each closed ended questions. Thus, this method helps the researchers' to examine the users' acceptance based on their response. The user acceptance of the system is computed manually using Equation (1).

$$AveS = SV1*\frac{nr1}{tnr} + SV2*\frac{nr2}{tnr} + ...\sum_{i=1}^{n} SVi*nri/tnr \quad (1)$$

Where, **AveS** average score, **SV** scale value, **tnr** total number of respondent and **nr** is number of respondent. To get the result of user acceptance average performance is calculated out 100%.

$$Avp = AveS/NS * 100 \quad (2)$$

Where, **NS** is number of scale and **Avp** is average performance.

The average score of each questionnaire is calculated using the sum of values of excellent, very good, good, fair and poor and divided the sum by four as illustrated in equation (1).

Table 1 Domain expert performance evaluation

No	Evaluation Questions	Poor (1)	Fair (2)	Good (3)	Very good (4)	Excellent (5)	Average score	Average performance. %
1	Simplicity to use and interact with the prototype system	0	1	0	3	2	4.00	80
2	Efficiency in time	0	0	1	2	3	4.33	86.6
3	The accuracy of the prototype system in reaching decision to identify the wheat disease	0	0	1	3	2	4.17	83.4
4	Coverage of domain knowledge is sufficient	0	0	0	3	3	4.50	90
5	The ability of the prototype system in making right conclusions and recommendations	0	0	1	2	3	4.33	86.6
6	Contribution of the prototype system in the domain area	0	0	0	2	4	4.67	93.3
		Total average					4.33	86.65

Based on data indicated in table1, 33.33% of the evaluators scored the simplicity to use and interact with the prototype system criteria of evaluation as excellent, 50% as very good, and 16.67% as fair. One evaluator rate the simplicity to use and interact with the system as fair. Because, the evaluator wants to retrieve queries via user interface in his local language and wants the system to make decisions in his local language, so as to understand the decisions made by the system. The efficiency in time of the proposed system showed a greater rate of efficiency, in which 50% of evaluators rated the system as excellent, 33.33% as very good, and the rest 16.67% as good. 33.33% of the respondents rated the accuracy of the prototype system in reaching decision to identify the wheat disease as excellent, 50% as very good and 16.67 % of them rated as fair.

And when asked if the prototype system incorporated sufficient knowledge to diagnose and treat wheat disease, 50% of the respondents rated the prototype system as excellent and 50% rated as very good. The ability of the prototype system in making right conclusions and recommendations, 50% is scored as excellent while 33.33 % as very good and 16.67% of the respondent scored it with good. Similarly, concerning the contribution of the system in the domain area, 66.67% of the respondents gave the prototype system excellent while 33.33% rated the prototype system as very good.

As a result, based on the responses of six system evaluators, the average performance obtained is 4.33 on scale of 5. This value is the result obtained from the values assigned for each close ended question. The result indicates that about 86.65% of evaluators are satisfied by the performance of the knowledge based system. This implies that the developed prototype system performs well in making right advice on diagnosing and treating wheat disease.

B. *Performance Testing*

Performance testing is the process of determining the accuracy of the developed system. The performance of the system is tested and validated using test case. A test case is a set of test inputs, execution conditions, and expected results developed for a particular objective, such as to exercise a particular program path or to verify compliance with a specific requirement [15]. Thus, a total of eighteen test cases are selected in order to validate the accuracy of a prototype knowledge based system. Test cases that have similar parameters with the prototype system are selected purposively. These cases are: root disease cases, leaf disease cases and grain disease cases. The testing procedure is carried out by system evaluators to classify the test cases as correctly diagnosed case or incorrectly diagnosed case and compare the decisions made by the system with that of the experts' decision on those cases. Then system evaluators validate the numbers of correct decisions made by the system. The result of the comparison shows that the rule based system has made close decision in the process of diagnosing wheat disease as human expert do. As indicated in table 2, the test case result provided by system evaluators showed that the proposed knowledge based system is 88.87% accurate in diagnosing wheat disease.

In table2, few abbreviations are used. CDC stands for correctly diagnosed cases, IC.DC stands for incorrectly diagnosed cases. Eighteen test cases are selected purposively to validate the accuracy of the system and six cases are assigned for each disease cases. As a result, for root disease cases five of them are correctly diagnosed from the given six cases. Similarly, from the given six cases again five of them are diagnosed correctly for leaf disease cases. Finally, the system correctly diagnosed all the given cases for grain disease cases and it achieves the maximum performance. The result indicated that all the cases are directly similar with knowledge incorporated in the knowledge base.

Table 2. Performance testing

Selected Cases	**No. of cases selected for testing**	**CDC**	**IC.DC**	**Accuracy**
Root disease cases	6	5	1	83.3%
Leaf disease cases	6	5	1	83.3%
Grain disease cases	6	6	0	100%
Total	18	16	2	88.87%

VII. RESULT AND DISCUSSION

As discussed in section VI under subsections *A* and *B*, the average evaluation result filled by the domain experts in the domain area is 86.65% and the accuracy of the prototype system is calculated as 88.87% respectively. The overall performance of the prototype system is 87.76%.

Depending on the results found the main strength of the prototype system are:

- The system is promising and helps to solve problems in the areas where there is lack of experienced and skilled agriculture experts are available
- The system is helpful to solve problems accurately and timely with the help of accumulated knowledge in the knowledge base.
- The system can reduce knowledge gap observed in agricultural professionals
- The system can act as a tool for knowledge sharing
- The system can help as knowledge sharing and training tool for DA (development agent) workers
- The system can improve the skill of DA workers in wheat disease identification and decision making.

Regardless of the strength of the system, the researchers have faced challenges. These challenges are:

- Evaluators want to see the severity of the infestation levels of the affected part of the wheat crop
- Users who lack computer skills and access might not implement it.
- The system needs to incorporate multiple languages to respond in their local language.
- The performance of the prototype system depends directly on the quality of the knowledge acquired from domain experts. However, knowledge elicitation from domain experts are the most difficult task due to the tacit nature of persons, knowledge is difficult to transfer to another person by means of writing it down.
- Language barriers and lack of adopted KBS technology in agricultural industry in Ethiopia hinders the system

not to register high performance.

VIII. CONCLUSION AND FUTURE WORK

In this paper, rule based knowledge based system is developed to diagnose wheat diseases. The system can serve as a knowledge sharing tool for inexperienced domain experts, especially for those in the remote areas with limited agricultural information. Moreover, the knowledge incorporated in the knowledge base contains all the necessary rules in order to diagnose wheat disease accurately.

The system provides advisory service for research centers and development agents to facilitate the diagnostic process. The system is evaluated using different evaluation methods and achieved 87.76% of the overall performance. The prototype system achieves a good performance and meets the objectives of the study. However, in order to make the system applicable in the domain area for diagnosis of wheat disease, the user interface should support local languages to meet the needs of local users and more research work must be done to incorporate high quality pictures which depict the symptoms in order to identify the damage level of the diseased part of the wheat crop.

IX. FUTURE WORK

Based on the finding made, further research can be done on the following areas for enhancing the performance of the knowledge based system.

- Nowadays our society at large uses mobile devices for communication. Therefore, incorporating a mobile knowledge based system is expected to provide the right information at the right time and place.
- Expert decision is regularly hard to measure with precise numerical data. So in the future, fuzzy set theory will need to be integrated in a proposed knowledge based system.
- Develop a hybrid knowledge based system for diagnosis and treatment of wheat disease in which the rule based and case based techniques will be integrated within the KB System.
- Research can be done on wheat crop nutrient deficiency disorder as the technology of KBS is applicable in this area.

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