Ontology based System for Pests and Disease Management of Grapes in India

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***Abstract* — About 35% of India's Gross National Product comes through agricultural sector. Any losses in gross agricultural product also affect Indian economy. Percentage of crop yield loss due to pests and dieses is considerable. As grapes are grown in most of states in India, it plays important role in gross crop yield. Having a computerized system for managing pests and disease occurring in grapes will help in increasing total yield of grapes. The paper proposes expert system for pest and disease management of grapes where we provide forecasting of probable pests and diseases. This work considers current weather conditions at grape farm location for forecasting. Knowledge base for pests and disease is generated by extracting information from internet and storing it as OWL document. Inference engine for grape expert system is based on fuzzy logic as weather conditions can logically be represented as fuzzy variables. It uses rule base developed by experts.**

***Keywords*— Expert system, OWL, Integrated pest management, Fuzzy inference system, Weather parameters**

I. Introduction

Agriculture is very important sector in Indian economy and grape is one of the major crops in Indian agriculture. Improvement in grape yield by managing pests and diseases will help improving gross national product.

Grape production gets affected by pests and diseases. Integrated pest management is most economical way of pest management. It considers relation between environment and pests occurring on crops considering current environmental conditions. Both weather forecasts and pest management techniques are available on internet. Integrated pest management can be done using this information. Using information technology for integrated pest management will reduce economic loss to grape growers and improve grape quality. We propose a system which extracts information from internet and provides forecasts of probable pests and diseases to grape growers.

An agricultural expert system can emulate knowledge and decision making capacity of farmers. With expert system, the knowledge and expertise of the grape expert can be easily adopted and utilized by many farmers and at different locations in India without presence of the grape expert. We cannot have precise definition of weather attributes such as warm and cold. Fuzzy set theory can be used to describe these imprecise attributes. Hence an expert system has been developed for grape pest management using fuzzy inference system. The knowledge base for grape pest management is developed as ontology as it can be easily shared by others systems. Using knowledge from knowledge base and with help of agricultural experts we have also developed rule base to be used by fuzzy inference system.

The paper is organized as follows: Section two gives overview of work done by other people for developing agricultural expert system. Section three describes architecture and implementation details of grape pest expert system. The performance evaluation of grape pest expert system has been done; details are given in section four. Conclusions are given in section five and references are provided at end of the paper.

II. Related Work

There are various expert systems for different crops like tomato, coffee and mango proposed by researchers. We summarize some of such systems in this section.

For management of Powdery Mildew in grapes a decision support system is developed by K Y Mundankar et al [1]. They estimate disease risk by considering plant growth stage and weather condition. All the details about weather condition, field condition and plant growth stage are taken from end user through software interface. Expert system provides information regarding fungicide spray name and its dose for various field and weather conditions.

An agent oriented method of developing decision support system for integrated production in agriculture is adopted by Ann Perini and Angelo Susi [2]. Software development phases for decision support system are described in detail in paper. The phases considered are early requirement analysis, late requirement analysis, architectural design and implementation for integrated production in agriculture. Various actors in agriculture production are listed and their relationship is shown in architectural design.

ViditaTilva, Jignesh Patel and Chetan Bhatt [12] proposed weather based expert system for forecasting disease on corn crop. They have used fuzzy logic technique for developing inference engine of expert system. They have used temperature, humidity and leaf wetness duration as weather parameters for defining fuzzy rules to estimate plant disease.

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They have defined five classes for input and output member functions as very high, high, medium, low and very low.

Rajkishore Prasad et al [17] proposed an expert system for the diagnosis of pests, diseases and disorders in Indian mango. A rule-based expert system is developed using ESTA; Expert System Shell for Text Animation. The system is based on answers to questions taken from farmers regarding disease symptoms. The knowledge base of expert system contains information about symptoms and remedies of fourteen diseases of Indian mango tree. Pictures of diseases are also displayed while answering to user's queries. They have used two types of diagnosis as consistency-based diagnosis and abductive diagnosis. For knowledge acquisition they used filed study approach consisting of three-tier interview with experts, field observation and by gleaning standard texts.

An expert system built using wxCLIPS inference engine for pest and disease management of Jamaican coffee by Gunjan Mansingh et al [18]. It is named as CPEST. They have used forward chaining as reasoning mechanism. The rule base of expert system contains hundred and fifty production rules. CPEST solves problem in three steps as general data-gathering phase, diagnosis and possible treatments and integration of treatments. Evaluation of quality of CPEST is also provided in three sections as validation, acceptance and effectiveness. For validation, different scenarios are considered and CPEST's recommendations are compared with expert's recommendations.

To diagnose honeybee pests, a rule-based expert system is described by B D Mahman et al [3]. System can be used by beekeepers. It is implemented using EXSYS Professional for Microsoft windows environment. Appropriate treatment and picture of pest is also provided by system. Inference engine uses backward chaining method. A set of if-then rules are contained in knowledge base of the expert system.

M P Bange et al [4] described development of a decision support system for pest management in Australian cotton systems called as CottonLOGIC. CottonLOGIC is developed to be used on handheld devices to collect data required for pest management from different locations. Information of the types of advantageous and harmful insects present at specific location and their quantity and stage of development is collected and provided to software. The software then predicts number of pests in future and tells whether pest numbers are over predefined economic thresholds. Software uses weather data for pest number prediction.

An expert system for identification of pests, diseases and weeds in olive crops is provided by J L Gonzalez-Andujar [5]. The knowledge base is created using interviewing technique and represented using IF-THEN rules. The knowledge base contains information for identification of nine weed species, fourteen insect species and fourteen diseases. Knowledge for expert system is acquired from experts using conventional interviewing techniques. For identification of pests and disease user is asked series of questions through interface which is to be answered in yes/no form.

Francois Rebaudo and Olivier Dangles [6] developed an agent based model for integrated pest management by coupling a pest model with a farmer behavior model. It is illustrated that how passive integrated pest management information diffusion is better than active diffusion. They provide insights of effective integrated pest management information diffusion strategies. Validation and verification results of expert system are also provided in paper.

Costas m Pontikakos et al [7] investigates effectiveness of location aware system of pest management for olive fruit fly. The described system uses information regarding olive fruit fly, meteorological conditions and spatiotemporal details of spraying areas. LAS have client-server architecture and it utilizes web services, geographic information system, expert system and multimedia technology.

A V Lopez-Morales et al [8] proposed an intelligent system for disease and pest diagnosis and control of tomatoes in greenhouses. It is named as JAPIEST. Probable development of diseases on tomatoes is detected by computing vapor pressure deficit. Disease detection results are provided with graphical support. Knowledge required by system is acquired from experts using dependency network.

III. Architecture of Grape Pest Expert System

An expert system for pest and disease management of grapes has been developed which follows three-tier architecture. Architecture is composed of the knowledge base layer, the inference layer and the user layer. Details are as follows:

A. Knowledge base layer

Knowledge base layer contains knowledge base of grape pests and diseases. Knowledge base contains symptoms, reasons and remedy for each pest and disease of grape. All information is stored as OWL document. OWL stands for Web ontology language which provides specifications for representing information as ontology. Being in ontology format it can be reused by any other system related to grapes.

Lot of information about integrated pest management is available on internet. Advantage of this fact is taken and assisted grape pest expert to extract information about grape pests from websites on integrated pest management and convert it in semantic form. As ontologies can be easily shared by software systems; once this information is available as ontology, it can be used many other expert systems for grapes. GrapeOntoGenerator is a java application developed for automated construction of Grape Pest Ontology. It provides easy to use interface for experts to generate ontology. System is developed in a way that experts do not need to know any technical details about ontology as shown in figure one. Figure two shows major steps followed by GrapeOntoGenerator. Grape pest details are extracted from websites and provided to GrapeOntoGenerator as text files. For extracting text we have developed a crawler which uses functions from JSOUP library.

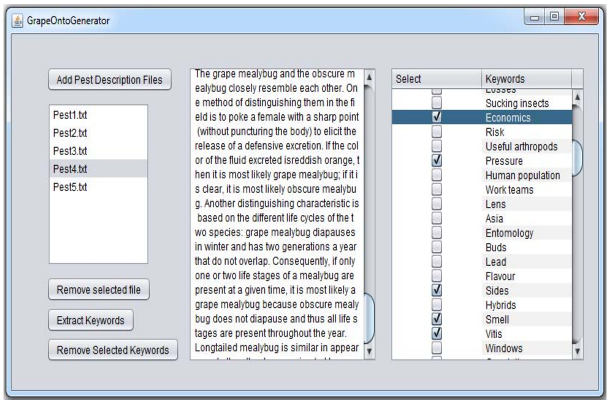

Fig. 1. GrapeOntoGenerator

Domain specific thesaurus named Agrovoc is used as controlled vocabulary for extracting keywords from text files. It is developed by FAO and available for free use. GrapeOntoGenerator analyzes key phrases to identify significant ones. It maps phrases in text to those in the thesaurus.

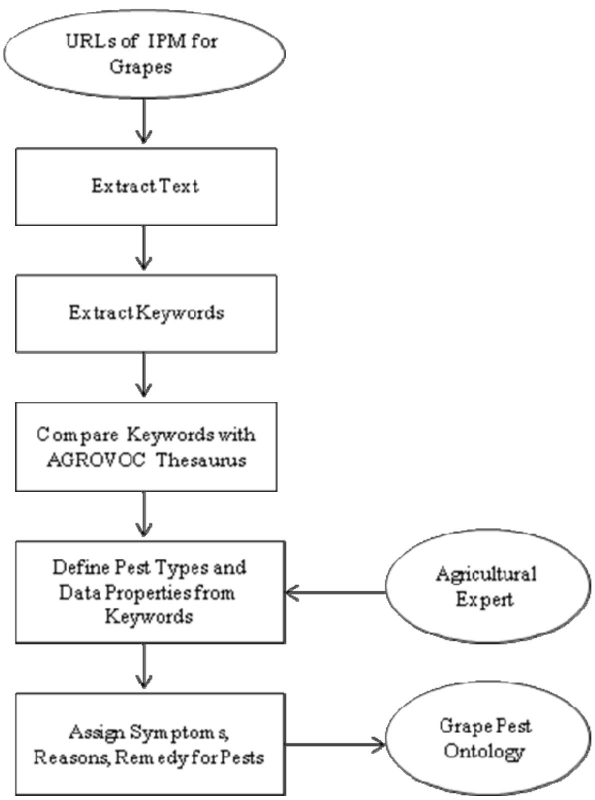

Fig. 2. Knowledge Base Generation

The text extracted from websites containing information about integrated pest management for grapes is segmented in individual tokens using StringTokenizer provided by java programming language. White space and punctuations have been considered for tokenization. Words containing numeric characters are directly eliminated from extracted keywords as any class or property in owl with word containing numeric character is not considered.

Second step is to remove stop words from text file as stopwords will be of no use for ontology building. It is done by comparing tokens with the list of stopwords in English.

Next step is stemming. The stemming algorithm used by GrapeOntoGenerator is developed by Porter Stemmer [9]. Stemming algorithm collects all stemmed versions of one word and returns a single word by transforming stems to its root form. Remaining keywords are then ranked alphabetically.

Most of the words used in grape pest ontology for defining classes and individuals are generally nouns and proper nouns in English sentences. So only nouns and proper nouns are extracted from stemmer output using openNLP POS tagger. Keywords with tags NN, NNP and NNPS are retained and passed to next step.

As the number of keywords extracted will be still large; one more filter is applied to keywords. GrapeOntoGenerator ranks extracted keywords using TFxIDF algorithm [10]. The algorithm compares frequency of keywords in a text file with its frequency in all remaining text files. Frequency of each keyword in single text file and in all text files is calculated and stored. TFxIDF for each keyword is calculated as

$$TFxIDF = \frac{\text{freq}(k,t)}{\text{size}(t)} \text{ X } \log_2 \frac{\text{docfreq}(k)}{n}$$

where k is keyword in text file t, and n size of all text files, freq(k,t) is frequency of keyword k in text file t and docfreq(k) is number of text files containing keyword k.Last step is to find relevance of these keywords to agricultural field. We search for existence of keyword in agricultural vocabulary AGROVOC. Keywords which do not exist in AGROVOC vocabulary are removed from keywords list.

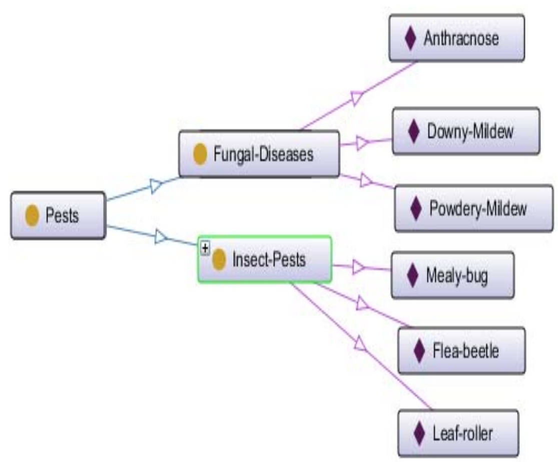

Fig. 3. Grape pests/diseases supported by expert system

All these steps are repeated for all text files generated by web crawler and keywords from each document are collected together. For adding new pest types and pest examples, two lists of keywords are prepared; one of nouns and second of proper nouns from keywords. These two lists are then available to grape expert to add pest name as class or pest example as an individual in ontology. GrapeOntoGenerator uses Protégé APIs for automatic construction of ontology.

B. Inference layer

Inference layer contains fuzzy logic based inference engine and weather data extractor module. The probability of a particular pest is categorized as very low, low, moderate, high, very high. Probability of occurrence of some pests is more at specific growth stage of grape.

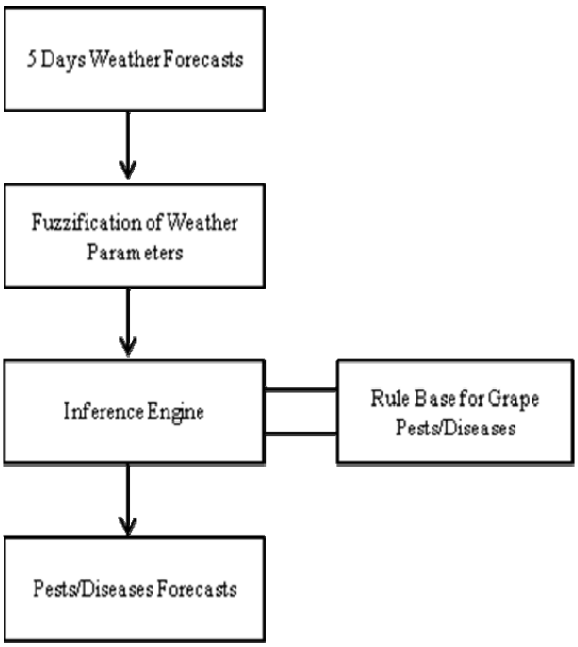

Fig. 4. Flow of Fuzzy Inference Expert System for Grapes

Grape growth is divided in eight stages as delay dormant, budbreak period, rapid shoot growth period, and bloom to veraison period, veraison period, harvest period, postharvest period and dormant period [11]. For weather conditions, three membership functions of temperature are defined as hot, warm and cold; membership functions for rainfall are defined as heavy, moderate and light; and membership functions for humidity are defined as high, medium and low. Rules for forecasting probability of occurrence as well as spread of grape pests and diseases are defined. Following are some examples:

If Temperature IS Warm And Humidity IS High And Growth Stage IS Vegetation
Then Probability (Occurrence (Downy Mildew)) IS Very High

If Rainfall IS Moderate
Then Probability (Spread (Downy Mildew) IS Very Low

If Temperature IS Warm AND Growth Stage IS BudBreak AND Humidity IS High
Then Probability (Occurrence (Mealy Bug)) IS Very High

If Temperature IS Hot AND Growth Stage IS Veraison AND Humidity IS Low
Then Probability (Occurrence (Mealy bug) IS Low

Weather forecasts of weather station nearest to farmer's location are considered for pest forecasting. Details of minimum temperature, maximum temperature, rainfall and humidity are extracted from meteorology websites hosted by government of India departments. Location based weather data extraction is done by extracting longitude and latitude of farmer's location using Location Manager Class from android library. Nearest weather station for farmer's location is found from geographic coordinates. Then weather details of nearest station are extracted from meteorological site using jsoup library.

Exact values of these parameters are used by fuzzification module and appropriate member functions representing current weather conditions are derived. The system uses jfuzzylogic open source library for developing inference engine. Fuzzy input variables defuzzify output variables and rules are defined in fuzzy control language and stored in .fcl file which is used for fuzzificztion.

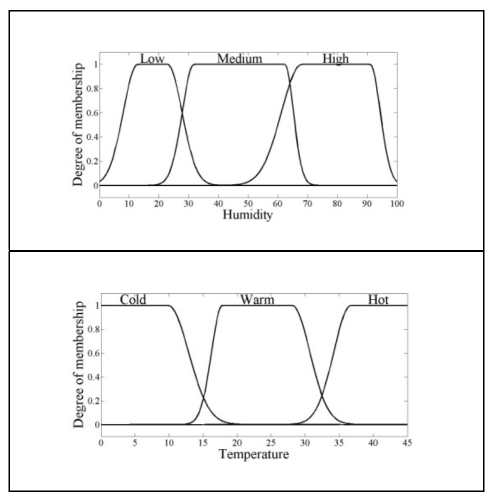

Fig. 5. Membership functions for temperature and humidity

Inference engine uses these membership functions and rules from gape pest rule base and outputs membership function for pests. Rules for six types of pests/disease in grapes namely powdery mildew, downy mildew, anthracnose, mealy bug, flea beetles, and leaf hopper have been defined.

C. User Layer

User Interface of expert system for grape growers developed as an android application to be used on mobile phone. Farmers first need to register on application before accessing grape pest details. When farmer starts application on mobile phone, his/her location is detected and sent to inference engine of grape expert system. General description, symptoms, reasons and remedy of each probable pest are provided to grape grower. Knowledge base of grape expert system also contains pictures of pests and diseases provided by experts. These pictures are displayed on mobile application along with general description. Figure six shows snapshot of mobile application providing details of powdery mildew and anthracnose.

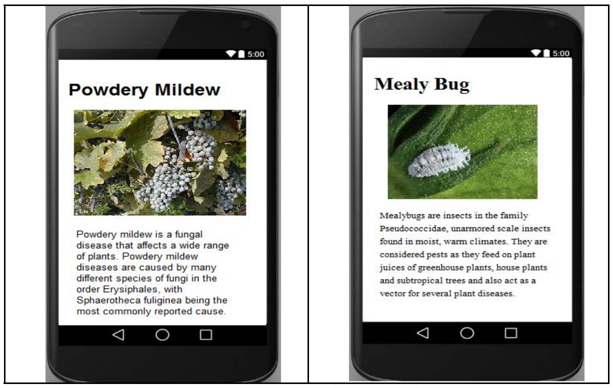

Fig. 6.Grape Pest Details on Mobile Interface

IV. Performance Evaluation

For checking validity of grape pest expert system and to verify its results, farmers at twenty different locations of India are asked to use grape pest expert system.

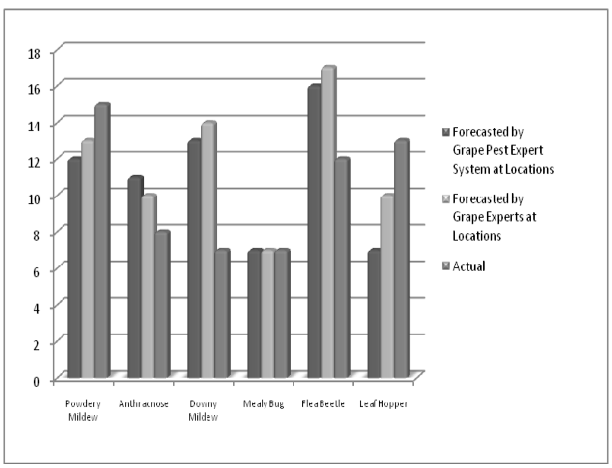

Fig. 7. Pest forecasting by Grape Pest Expert System

We listed pests forecasted by grape pest expert system and compared it with actual pests and techniques used by farmers at these locations. We also considered experts opinion about probable pests during given weather conditions. We have compared probable occurrence of seven pests on grapes namely powdery mildew, anthracnose, downy mildew, milibug, fleabeetle and leafhopper. Figure seven shows graph of results of this comparison.

V. Conclusion

Integrated pest management provides most economic way of pest management considering current environmental conditions. As a part of IPM, architecture of expert system for disease and pest management in grapes is presented in this paper. Implementation details for three layers of experts system namely database layer, application layer and client layer are explained thoroughly. With proposed system expert knowledge is reachable for farmers. Location aware forecasting of pests and diseases will help farmer to reduce loss in grape yield. With rule base and fuzzy inference engine system tris to provide precise forecasting of pests. Weather parameters such as temperature, humidity and rainfall are considered during formation of rule base. Being mobile phone application, expert system can be accessed by farmers at any time, any location and without requiring high end tools.

As part of future scope, proposed work looks forward to consider more parameters for forecasting pest occurrence like soil conditions, leaf wet details and improve accuracy of system. It also plans to extend AgroKanti for other important crops in India like rice, wheat, cotton and sugarcane.

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