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An intelligent mobile application for diagnosis of crop diseases in Pakistan using fuzzy inference system

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ABSTRACT

South Asian countries are amongst the largest producers of crops with favourable climate conditions and fertile soil. However, traditional agricultural mechanisms are in place and inadequate effort has been put into exploit the usage of technology. One of the main problems being faced by agriculture sector in Pakistan and other developing countries is that crop diseases are not diagnosed timely and efficiently. Conventional methods for disease diagnosis in crops lead to less accurate and inefficient diagnosis, consequently leading to low productivity. In this paper, an intelligent approach for the diagnosis of crop diseases is proposed which is capable of working over Android mobile devices using fuzzy inference system as the main decision making engine at the backend. The system is capable enough to communicate to the farmers in Pakistan in their local language Urdu and assist them in diagnosing diseases in their crops. Agriculture experts in government sector can get equal benefit from it in diagnosis and prevention of crops diseases. It takes symptoms of the crops as input with a provision of vague input and generates the output in the form of diagnosed disease using its inference engine. The proposed system caters two main crops of Pakistan, cotton and wheat and is capable to diagnose their main diseases. The proposed system has been tested on a pool of 100 real crop problems and its inference engine has shown excellent performance in prediction of the right disease which is up to 99% accurate.

1. Introduction

According to Food and Agriculture Organisation of The United Nations (Food, 2013), Pakistan is a rich country in agriculture sector since its inception and it has a vast arable land with the largest and oldest irrigation system in the entire region. Pakistan is the 4th largest cotton producing country and 7th largest wheat producing country besides many other crops like sugarcane (Food, 2013). But unfortunately, agriculture contribution in country's gross domestic product (GDP) has declined from 54% to 24.6% over the last decade, and total crop production in Pakistan is almost 50% below its potential (Sindhu et al., 2010; Malik, 2012; G. of Pakistan, 2014). Despite of being one of the largest producers of crops, Pakistan is facing many difficulties and problems in the agriculture sector since last decade, which is mainly because of issues like lack of relevant research and lack of state of the art facilities. In agriculture extensions departments, there is lack of trained experts and modern equipment which do not help the farmers adequately to assist in solving their problems including efficient disease diagnosis. Disease diagnosis is inefficient and less accurate due to unavailability of experts in the field specifically the rural areas which encompass about 70% area of the country.

In this research work, an intelligent expert system for diagnosing the crop diseases using fuzzy logic based decision making algorithm has been proposed. This study focuses on two main crops in Pakistan: wheat and cotton. The system is capable to diagnose twenty-one common diseases of wheat and cotton. Proposed architecture has been developed using fuzzy logic as decision making engine at the backend and Android application has been designed for the front end using jFuzzylite library. jFuzzylite library (Rada-Vilela, 2013) is an open source library developed for building fuzzy inferences systems in Java and Android. In rural Pakistan, farmers are not much literate, so there is a provision of using the local language Urdu to interact with the mobile application along with default provision of English language. There are two main reasons of applying fuzzy logic for decision making in the proposed framework. First reason is that rules are derived from expert knowledge which is described in natural language and fuzzy logic is a powerful knowledge representation mechanism for linguistic knowledge. Second reason is that it handles the vagueness and uncertainty inherent in the problem domain which is not handled by classical set theory (Zadeh, 1994; Mamdani, 1974). It gives the farmer and other agriculture related people provision to provide vague inputs as intuitive guesses when they are not much clear. Different aggregation and defuzzification methods

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have been implemented for the evaluation purpose. Based on the empirical results, the best combination of these methods is recommended to be used at practical scale. It has been found that the optimal combination is to set max method for aggregation and middle of maximum (mom) method for defuzzification.

Rest of the paper is organised as follows: Section 2 discusses the problem domain and related work in literature, Section 3 describes the fundamental concepts of fuzzy logic and working mechanism of fuzzy inference system, Section 4 explains the proposed approach, Section 5 presents the results of the proposed system and their analysis and Section 6 concludes the paper highlighting some of the prominent future directions of this work.

2. Background and related work

Incorrect and late disease diagnosis is one of major problems for low yield of crops in the developing countries including Pakistan (Anwar et al., 1993; Mukhtar, 2009). Some of major cotton diseases are leaf curl virus, root rot and boll rot. Some of the major wheat diseases include black stem rust, yellow or stripe rust, loose smut and flag smut (ur Rehman Rattu et al., 2011).

In recent years, technological research in this domain has shown significant economical benefits (Evenson et al., 1979; Gollin et al., 2002). It shows that agriculture productivity continues to grow. Technology adaptation has resulted into many successful expert systems in different domains including healthcare, economics and market trends, education, weather systems and different planning activities (Das et al., 2016; Dagar et al., 2015; Moghaddam et al., 2016; Gokmen et al., 2010; Abhishek et al., 2012).

Pakistan Advertiser Society (Society, 2018) has revealed statistics related to the usage patterns of smartphones in Pakistan. 72% of Pakistani population uses smartphones. Out of these smartphone users, 68% are Android users. 60% of the users use more than one cell phone. Due to wide spread and massive growth of 3G and 4G networks across the country, smartphone market is continuously growing at a fast pace.

Similarly, different approaches and applications have been proposed in literature to benefit the agriculture sector through technology specifically disease diagnosis systems. In Rafea et al. (1993), data acquisition framework has been proposed to gather crop disease data based on conventional waterfall model. In Rafea et al. (2003), authors presented different techniques and methodologies for the development of the expert systems at CLAES (The Central Laboratory For Agricultural Expert Systems) in Egypt. Mining the classification rules for Egyptian rice disease is another work done by CLAES (El-Telbany et al., 2006). The authors used C4.5 decision tree algorithm for mining the classification rules and compare the results with neural networks. In Rafea and Shaalan (1996), the performance of Cucumber Expert System (CUPTEX) and the Citrus Expert System (CITEX) has been described as a training tool in agriculture sector. There were four subsystems named irrigation, fertilisation, verification and treatment for CUPTEX and CITEX. After different experiments, there was enhancements in the performance.

Different data mining techniques have been used for the early detection of fruit disease (Ilic et al., 2015). Weather data and spores data were collected using automatic meteorological stations and spore traps respectively. Different data mining techniques including J48, sequential minimal optimisation (SMO) and ZeroR have been used to measure percentage of correctly classified instances, standard deviation, mean absolute error and relative absolute error. J48 algorithm was chosen to train the fruit infection prediction model because it correctly classified about 90% of the total instances (Ilic et al., 2015).

In China, a web-based intelligent diagnosis system for cotton disease control has been built using back-propagation neural network (Li et al., 2010). This tool has been tested on eight different species of cotton diseases. In India, a fuzzy logic based approach has been used for disease diagnosis of oilseeds crops, soybean, groundnut and rapeseed-mustard (Kannan and Hemalatha, 2012). In Khan et al. (2008), an expert system for wheat crop has been proposed using rule based inferences. In Sarangi et al. (2016), a framework has been developed to bridge the communication between automated cloud based services and crops disease recognition algorithms. The performance has been evaluated under different parametric configurations. In Camargo et al. (2012), classification algorithms have been implemented to advise the farmers in locating plant disorders. The system is capable to suggest countermeasures as well against different disorders.

In Naik and Sannakki (2014), an image processing based method has been proposed to diagnose diseases of plants. Image of plant leaf is segmented using clustering methods to locate the effected part of leaf. Based on the features of the effected part, disease is approximated using a fuzzy logic based classifier. In Shafinah et al. (2013), a survey of expert systems have been presented to manage crop diseases. The authors conclude that limited theoretical frameworks have been proposed and their practical aspect needs significant work. A rule-based expert system has been proposed for fruit diseases in Dewanto and Lukas (2014). In Nasar et al. (2008), authors have proposed a descriptive and graphical method to locate plant disorders and prototyped it at a limited scale. A knowledge acquisition and management tool for storing and structuring data of crop diseases has been proposed in Kolhe et al. (2009) which may later serve as a foundation to diagnose crop diseases. A web-based tool has been designed which exploits a rule promotion approach to diagnose diseases of oilseeds crops (Kolhe et al., 2011). A neural networks based approach has been proposed in Li et al. (2010) to diagnose cotton diseases in China using back propagation algorithm. A Windows phone based mobile application has been presented in Petrellis (2017). It assists in diagnosing plant diseases at early stage using image processing techniques. In P.S. University (2018), a smartphone based application has been introduced in rural Africa to diagnose crop diseases focusing on tuber and banana diseases. Plantix is another mobile application for advising the farmers, gardeners and extension workers in agriculture sector (P.S. University, 2018b). It focuses on disease diagnosis using leaf images. A deep neural network has been deployed for image-based disease diagnosis of plants using a repository of labeled images as training data set in Mohanty et al. (2016). In Petrellis (2015), an image processing based approach has been presented which may diagnose crop diseases at early stage using extracted symptoms of different visible parts like stem and leaves. In Pongnumkul et al. (2015), systematic literature review has been conducted to study the usage of different sensors of smartphones for agriculture purposes. Sensors for global positioning system and camera are the most widely used sensors of smartphones which have been deployed to collect data from fields.

Besides artificial intelligence based diagnostic systems, many mobile applications have been developed across the globe to disseminate relevant information to the farmers. Reuters Market Light (RML) is a paid mobile application to update the farmers with crop prices and weather (SourceTrace, 2017). Mobile applications developed by Jayalaxmi agrotech are amongst the most widely used agricultural applications in India to advise the farmers through delivering relevant information in local languages (SourceTrace, 2017). FarmerLink is an application for the farmer community in Philippine to help them manage crops through satellite as well as ground data (SourceTrace, 2017). In Gupta (2018), top five agricultural applications of 2017 have been presented including CCMobile for connecting farmers for crop management and optimisation, SprayGuide for pesticides management, IFFCO Kisan for connecting the farmers with domain experts for guidance, AgMobile for informed decision making about fertiliser and pesticides based on soil analysis and MachineyGuide for advising the farmers on agricultural machinery usage. In Jain et al. (2015), a survey has been conducted to assess the acceptability and need of the farmers in India. Focus has been to incorporate mobile technology contextualised in the local languages to build future agriculture related systems. In Jain et al. (2016), a mobile application has been designed which uses fuzzy logic to contextualise information for the farmers