Volume- 5
Issue- II
December-2020
Rajarata University Journal
ISSN: 2362-0080
www.ruj.ac.lk/journals/

Category: Case Study

A Conceptual Architecture for Agricultural Mobile-based Application using Participatory Sensing: A Case study for Pest and Disease Management

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ARTICLE DETAILS

Article History
Published Online:
30th December 2020

Keywords
Participatory sensing; conceptual architecture for mobile application; emoticons, ontology evolving, agriculture.

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ABSTRACT

A smart mobile phone is a magic device that makes a strong information environment. Using sensory information through mobile phones can be formulated and can then be used to form a body of knowledge. We have already developed a mobile-based application for Sri Lankan farmers to help their farming activities. Agricultural information and knowledge that is required by this mobile application is represented in an ontological knowledge base. However, there are some key challenges faced by farmers in Sri Lanka due to lack of information such as current status of pest and disease attacks and their management. In this study, we explore how the Participatory Sensing concept can be used to enhance the existing mobile-based application to make available further actionable information that will assist farmers in successful farming with respect to pest and disease management. Importance of adding farmers' feelings as emoticons was studied in analyzing the current situation with respect to pest and disease attacks. The Emoji icons shared by the farmers related to their expression along with the other relevant details that they observe on a pest/disease attack could be used to identify the severity levels through information aggregation. This aggregated information will enable farmers to understand the current status of the pest/decease attack which can later be used for predictions. In this paper, we elaborate the proposed conceptual solution architecture of this enhancement based on participatory sensing with respect to pest and disease management.

1. Introduction

We have developeda user-centered ontology to provide necessary agricultural information and relevant knowledge that can be queried based on the farmer context [1]. A Mobile-based application was developed using this ontology to provide needed information and knowledge to farmers [2]. In this paper, we present our attempt to make information further actionable through the concept of participatory sensing using the existing mobile application. This study was carried out as a part of the International Collaborative research project aiming to develop mobile-based information systems to support livelihoods of people in the developing countries [3].

Through the existing mobile-based application (refer http://www.govinena.lk), the agricultural information needed by the farmers is provided based on their choice of context. Some information and knowledge provided by the system includes the suitable crops and varieties to grow based on the region of a farmer, the problems in crop cultivating (e.g. Disease, Pest, Weed) specific to the crop, the symptoms of each problem, remedies to those problems with respect to the preferences of the farmers, and relevant fertilizers and their usage. Other than the above information, it provides more information such as including the price list of pesticides and fertilizers from different vendors, and a profit calculator etc. [2].

We know that people take photos of important events to remind them the memories of the event in the future. We can use this natural human tendency to identify significant events related to the person or situation (from memories in information sources).

Smart Mobile phone is a device with a camera and sensors through which the real-time data can be obtained from people with respect to their environment. Moreover, a person can share context specific meta-information relating to his/her real situation with others along with the details relevant to that event, such as time, location and images with descriptions. Then, this data, which can be referred to as sensory information is possible to be used to form a body of knowledge. For example, by aggregating such meta-information from large number of participants it is possible to extract even more useful information such as overall status of the current situation. The key challenging task in this field is the lack of models to capture the data semantically and to convert this data into useful information and/or knowledge that can be used to make better decisions.

Creating such an environment within the farmer community is essential to support real-time decision making. To this end, we did several surveys to examine the key challenges faced by farmers in Sri Lanka by specially covering the areas: Nuwara-Eliya, Welimada, and Boralanda in Budulla district. We observed that by analyzing the findings,managing pest and disease attacks are the key challenges faced by farmers. Further, most of the farmers spend a lot of money to prevent and control the pest and disease attacks[4,5].Based on the empirical study of information needs of farmers conducted by Mahindarathne and Min, it has been revealed that the information related to the pest and diseases takes a high priority of the information needs [4]. By considering above facts we focused our attention to design a model incorporating sensory information from the participants, especially to enable a better decision-making process in the domain of agriculture related to the pest and disease management.

"*Participatory Sensing (PS) is the process whereby individuals and communities use ever-more-capable mobile phones and cloud services to collect and analyze systematic data for use in discovery* [6]".

The concept of Participatory Sensing (PS) has been explored as a mechanism, which can be introduced to make an effective agriculture information system [7-12].For instance, the Rural Participatory Sensing framework (RuPS) is a mobile-based system, which has been developed for Indian farmers to monitor the crops with the support of experts[8]. The mobile application in crop health assessment with PS has been introduced to detect the diseases in early stages [7]. Moreover, 3D PS with Mobile Devices for Crop Height Assessment has been used to measure the height of maize in Heidelberg, Germany [9]. However, in Sri Lankan context, use of the participatory sensing for agriculture applications has not been extensively studied. As such, we propose a model to incorporate PS to our existing mobile-based application to support farmers in decision making process related to pest and disease management.

We studied how we can apply the features behind the smart phones to be used to implement participatory sensing in the domain of agriculture. As a result, the sharing of images, feelings and text information with respect to pest and decease incidences were introduced to the existing mobile application. In this paper, we focus the farming problems especially pest and diseases management as it is the main challenge in the growing stage. Using the proposed model each stakeholder is able to get connected via the mobile application enabling them to share their situations particularly the pest decease incidences, their emotional feelings, severity level of the incidence and the solutions that they adopt. This sensory information would enable other farmers in the community to take better decisions. For example, before cultivation of crops, farmers can analyze the shared situations/events by others to get an idea in growing problems and in turn to find suitable solutions, and to decide upon the crops for cultivation. Further, the aggregated information using these situations, will enable to understand the overall current status with respect to a pest/decease outbreak. Producing this knowledge about the current status will facilitate farmers to get ready to face and mitigate those attacks successfully.

The remainder of the paper is organized as follows. Section 2 presents Material and Methods that explain the design of proposed approach of application of participatory sensing to manage pest and disease attacks. Overview of the proposed system is described under Results and Discussion (Section 3). Related Literature is discussed in Section 4. Finally, Section 5 summarizes the approach and concludes the paper.

2. Material and Methods

Now let us explore how the above concept (Participatory Sensing) can be applied to the domain of agriculture for better decision marking. Farmers are the main stakeholders in this domain. There are six stages (crop selection, pre-sowing, growing, harvesting, post-harvesting and selling) that have been defined in farming lifecycle in Sri Lankan context and farmers are seeking information in each stage [1]. Therefore, rank of farmers' information needs was considered in defining the events in the mobile application. Based on the Scores and Ranks of Informational Needs defined by Mahindarathne and Min [4], fertilizer supply, pest and diseases and planting materials are the highest ranked information needs in a farmers' community. When considering farming cycle, the highest ranked information needs are concentrated in the growing stage. Thus, possible meta-information that can be associated with an event was reviewed relating to the growing stage. We have reviewed some of the possible meta-information that we can associate with an event relating to the agriculture domain. The following events were identified with respect to the growing stage:

- *Event name: Healthy Growing*: this event describes the healthiness of crop cultivation
- *Other events such as Disease*, *Pest*, *Weed*, and *Weather Damage* (climatic/natural disasters) are identified with respect to the growing stage and describe the level of damage of the cultivation

In the proposed application, farmers can take photos by selecting an event with an emoticon. An emoticon is some graphical representation that is used to make meaningful communication [13]. For this, emoticons were introduced to identify the severity of the farming events. In general, there are lots of emoticons available in online applications to express emotions. Among them, a set of emotions were selected by considering two criteria. They are: 1) understandability and 2) ability of representing the actual feelings of farmers. For that, Plutchik's Psycho-evolutionary Theory of Emotion [14] was referred and selected the primary emotions: Joy, Sadness, Fear, Anger, Surprise and Anticipation. Then, emoticons were categorized under these emotions. Emojipedia [15]is a search engine, which allows to browse the emoticons by name, platform and category. Hence, Emojipedia was used to access different emotions for the categorization. The categorized emoticons were given to the farmers who have experience in smart phone applications and three Agriculture Instructors (AIs) who are assigned to the areas of Nuwara-Eliya, Walimada and Boralanda to select suitable emotions for each emotion based on their understandability and feelings. In this regard, we purposefully ignored the farmers who do not have adequate experience in mobile applications as they would take a significant time to adapt to the new technologies [16]. Thereafter, a set of suitable emotions which represents feelings related to disease and pest events were selected based on the comments given in the interviews conducted with the agriculture experts. Thus, emoji level of severity of an event is categorized into four levels (Mild, Medium, Bad, Very bad).

By selecting any of the events mentioned above (eg: Healthy Growing, Disease, Pest, Weed, and Weather Damage), farmers can express their experiences/feelings using special emojis related to their class/category as follows:

- Photo of a Significant Event (Healthy Growing, Disease, Pest, Weed, or Weather Damage)
- Severity of event using Emoji(expressions given below)

➢ *Healthy Growing:*Emoji➔ Poor, Bad, Average, Good

➢ *Disease:*Emoji➔ Mild, Medium, Bad, Very bad

➢ *Pest:*Emoji➔ Mild, Medium, Bad, Very bad

➢ *Weed:*Emoji➔ Mild, Medium, Bad, Very bad

➢ *Weather Damage:*Emoji➔ Mild, Medium, Bad, Very bad

In order to provide relevant information to the farmers, capturing meta-information related to the farmers' context is important. For an instance, if the event is "Disease" then the crop name, symptoms, variety, location etc. needs to be considered to provide appropriate information. Thus, after taking a photo with an emoticon, information tagging interface allows farmers to add meta-information related to the events. For an example, if the disease event is a bacterial infection like bacterial wilt in Granola potatoes, the meta-information to be added is: Crop: 'Potato', Variety: 'Granola', Symptoms: 'Wilting leaves, Wilting Stem', Location: 'Boralanda' and the date and time. By aggregating that captured meta-information from a large number of farmers, we can derive additional information and new knowledge about evolving situations. For example, by analyzing and aggregating this information (i.e. emoji and meta-information), a prediction can be done such as there is a trend for a disease outbreak to specific crop in a specific area. Then the farmers are aware of that and relevant authorities will make warnings and make actions to prevent that immediately.

Moreover, the farmer can use proposed application to capture many moments along with photos and related information. For an instance, if a farmer successfully prevents a pest attack by applying a new pesticide, then the farmer can share this event by attaching an image of plants with feelings (emoji: happy), the place and the solution has been taken. However, they may also keep these private only for his/her use. This may help him/her privately review what he/she has done and what worked or not worked.

In addition to that, farmers are able to access control methods and recommendations through the system by sharing meta-information related to their growing problem events. For that, the system has been enriched with agricultural ontological knowledge base which has been developed to represent the crop knowledge in a context specific manner [1]. After capturing the meta-information ,the system can formulate the queries (SPARQL query - SPARQL Protocol and RDF Query Language) that are used to query the ontological knowledgebase which is in RDF format (Resource Description Framework). Then the retrieved knowledge from ontology such as control methods: for example, use recommended fungicide, collect and destroy the caterpillars, etc. will be provided to the user to help them to make better decisions.

GUI Design for "Disease" Event

In this section, we will describe the proposed user interface design of the mobile-based system for the "Disease" event. The description of each interface in Figure 1 is discussed below.

- *Step 01:* Capture the picture of crop which is effected by the disease with emoji using smart phone camera.
  - Select damage level/range as emoji (e.g. Mild, Medium, Bad, Very bad)
  - For example, select "Bad" then take a photo (see Figure 1 related to the Step 1)
- *Step 02:* Add additional information→crop name, symptoms, and etc. (use Edit option: Edit, Tag, Delete) – see Edit Menu in the Figure 1 (Step 2).

The system provides the facility to add the crop name. Then the system lists:

- all the symptoms with respect to the crop (then the user can select the symptoms with respect to their context) (see Step 2-(a)).
- all the diseases with respect to the crop (and the symptoms); (then the user can select the specific disease if they know it – selection is optional, see Step 2-(b)).

Step 2- (c): After adding additional information, the user can save the details using "Done" button.

- *Step 03:* User can select similar pictures with respect to his/her image (refer Step 3 in the Figure 1) and share with the system.

  User can view all the details with respect to the event (e.g. all the information about emoji, crop, disease, location and control methods with respect to the "Disease" Event)
- *Step 04: User can view control methods and* recommendations provided through the system specific to the shared growing problem events(i.e. can view control methods with respect to the crop, specific disease, etc.)
- *Step 05:* Further, user can delete the photos which are only stored in their device. Deletion will not be applied for shared images.

Based on the farmers' information, the system provides relevant control methods using the agriculture ontological knowledgebase. Then farmers can view all the information with respect to the event. For example, event details are: Bad (emoji), on Tue (date), at Matara (location), Tomato (crop), Bacterial wilt (disease name), Control methods 2,3 (control methods)).By analyzing and aggregating the farmers' inputs further actionable information can be predicted. Some examples are listed below.

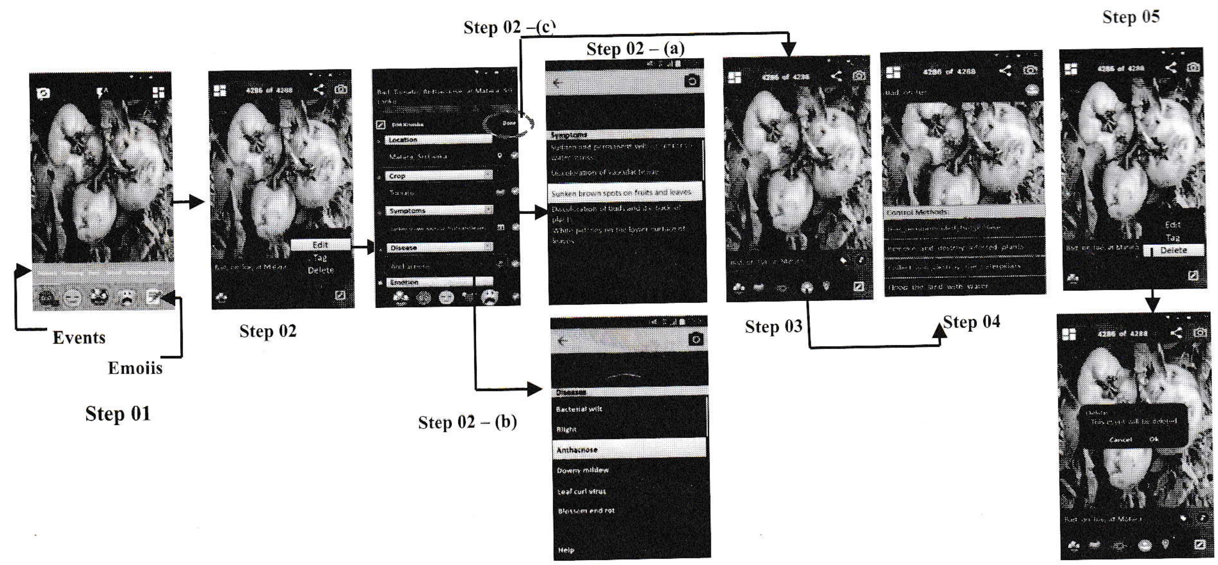

Figure 1: Proposed Mobile-based interfaces for the "Disease" Event

- Which crops are badly affected in a specific area or location?
- Is there a trend for a disease outbreak for specific crop in specific region?
- What are the regions that are badly affected by specified disease of a crop?

The predicted information will help farmers as well as the other stakeholders (domain experts, policy makers, or government) in marking better decisions. Moreover, this concept (participatory sensing) can be effectively used for analyzing the real-time data in weather parameters.

3. Results and Discussion

The designed architecture of the Proposed System is shown in Figure 2. The frontend design of this system (see Figure 1) is refined based on the comments and suggestions made by the AIs and backend is designed with the database and online crop knowledgebase discussed in [1]. All the data and information will be shared through web services. The proposed concept to the existing mobile-based application provides the solutions for queries of farmers in each agricultural event mentioned above. For an instance, consider the disease event. Initially, farmer can share disease related questions through this system after adding metadata such as Geo-location, date and time, crop details and etc. Then, SPARQL (SPARQL Protocol and RDF Query Language) queries are generated by analyzing shared metadata. This SPAQRL queries are sent to the RDF ontology (Resource Description Framework ontological knowledge base) to query the answer for farmers' questions. The ontological knowledgebase has been modeled using OWL (Web Ontology Language) and converted into the RDF (Resource Description Framework) format in order to support for querying through SPARQL (see Figure 2). For disease event, knowledgebase provides a set of control methods to restrain the diseases of the crop. This set of control methods are converted into mobile compatible data and send to the farmers' mobile application. Farmer can view the control methods related to the specific diseases. The database stores other relevant information which are not related for agricultural events such as farmer details: name, address, contact numbers, farm details etc.

4. Related Works

There are some research studies in agriculture domain that introduce mobile-based application with participatory sensing [7-12]. These studies have been carried out in developing countries to disseminate information by linking the farmers with agriculture experts.

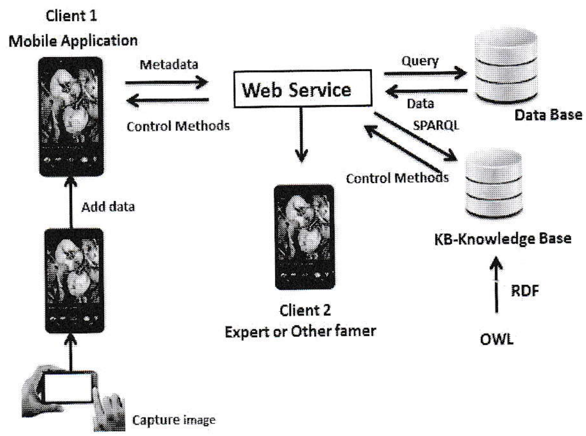

Figure 2.Architecture of the proposed system

Previous literature explained a mobile application (mKRISH mobile client application) that is used to detect the late blight disease in potato by analyzing symptoms, as observed by the farmers[17]. Using mKRISHI mobile application, a farmer can ask any query from an expert in the form of voice, text, and images. Further, atmospheric, soil and plant related parameters, observed by the weather station deployed in the farm, are also made available to an expert for detailed investigation. In this case, mKRISHI framework combines the existing forecast models and diagnostic techniques to provide expert's advice related to various domains such as farming, education, etc., to farmers. This, in turn, reduces the disease risk along with avoiding the unnecessary application of fungicides and focuses on timely detection of late blight in potato crop. In here, experts should be available to continue the advisory system.

Due to a small number of experts and large number of distributed farms, it becomes increasingly difficult to obtain reliable ground data about the emerging and highly resistant pests and diseases. To solve this problem, Mohite et al., have introduced a mobile application for crop monitoring in rural areas [8]. That is useful for farmers to monitor the situation on the farms to detect the problems related to pests, diseases, and nutrient disorders. The RuPS framework comprises of a RuPS mobile application, which facilitates farmers to report Geo-tagged events using images and voice clips along with the information tags (diseases, pests, nutrient disorders). A remotely located agricultural expert validates the information tags provided by the farmers and renders the advisory services through the RuPS application. Both of the applications use participatory sensing concept to solve the existing problem in farming by engaging with experts. The availability of expert in right time cannot be assured. Therefore, an option is needed for solving farmers' queries without intervention of an expert.

The mobile application PlantVillageNuru has been introduced for the developing countries [10]. It is a powerful application that has been developed incorporating the participatory crowd sensing techniques to detect plant diseases in early stages. Through that application, the plant images are analyzed with the support of an Artificial Intelligence engine to recognize health issues. Even though this approach is very similar to our concept, it only focuses the disease dimension of the farming events and no application of sharing events with expressions/feelings.

When considering the technological approach in our system, we take advantage of ontological knowledgebase to provide answer/solution minimizing the expert's intervention. The feasibility of querying information/knowledge according to the meta-information was verified through existing research works. IMGpedia is an ontological knowledgebase which contains metadata such as imagetitle, subject, source, format, description, date, size, location, etc. It is an extension of DBpedia (https://wiki.dbpedia.org/) that contains the extracted structured content from wikipedia. In this system, SPARQL has been extended to execute content-based analysis at runtime, based on image data [18]. Moreover, BioPortal is a repository of biomedical ontologies. These ontologies were developed in OWL, OBO (Open Biomedical Ontology) and other languages, as well as a large number of medical terminologies that the US National Library of Medicine distributes in its own proprietary format. Under this research, Salvadores et al., have published the RDF based serializations of all these ontologies and their metadata at http://sparql.bioontology.org/[19]. This endpoint can be queried with SPARQL. All the mentioned approaches have provided methods to query metadata using SPARQL. The proposed approach in our study is the inverse of these cases. We need to create the SPARQL queries based on the given metadata of mobile application to generate the relevant control methods from RDF graphs.

In the domain of Sri Lankan agriculture, there are few studies which have introduced mobile applications that allows farmers to send their queries as a message or voice related to price details, crop varieties, diseases and control methods [20,21]. However, these mobile-based applications disseminate information to the farmers by considering one or few aspects, for instance, market price and vendors, crop details, pest and diseases, weather details.

In proposed extension to the existing mobile-based application ("Govi-Nena"), the domain knowledge represented in the ontology is analyzed to answer the farmer queries that can be matched with the details of the farm, symptoms of the diseases, crop knowledge and the emoji level of severity of event provided by the farmer. Therefore, our study explored the ways of using the advancement of smart phone sensors and allows farmers to send farm related details via mobile sensors to the system and make an effective information flow with the agriculture information system. We have received good comments/feedback and suggestions from the AIs to the paper prototype which is developed based on the proposed approach. As this is an ongoing project we are implementing the paper prototype of proposed designed approach.

5. Conclusion

In this research, we have designed a conceptual architecture to the existing mobile-based application ("Govi-Nena")to better manage the pest and disease attacks exploring participatory sensing. The importance of this approach is capturing of sensitive data with the feelings of users. The Emoji icons are defined to identify the different levels of expressions of the farmers and those are linked with the other related information of farmers' queries. Ontological knowledgebase provides the relevant answers to these queries by considering all the information. Further, existing ontological knowledgebase can be enhanced through this model by getting more farmer inputs. By validating those farmer inputs (for example new diseases or symptoms) the knowledgebase can be enriched.

Finally, the proposed architecture to report and share the farmer situations/ events is shown in Figure 1 and 2. It analyzes the farmers' inputs further to make actionable information. In addition, the aggregated farmers' inputs can be used to predict future situations and that will help better planning for future disasters in farming.

Acknowledgement

We acknowledge the valuable assistance from other researchers working on the Govi-Nena Project. This research was supported by the Accelerating Higher Education Expansion and Development (AHEAD) Operation of the Ministry of Higher Education funded by the World Bank. Further, authors would like to thank Prof. Ramesh Jain, University of California, Irvine, California for his expert advice and encouragement throughout this research.

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