

User Centered Ontology for Sri Lankan Agriculture Domain

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Abstract— People working in the agriculture domain in Sri Lanka are affected by not being able to get vital information required to support their domain related activities in a timely manner. Some of the required information can be found in government websites, agriculture department leaflets, newspapers, etc. The required information is hard to find from these knowledge sources due to its unstructured, incomplete, varied formats, and lack of targeted delivery methods. Thus finding the right information within the context in which information is required in a timely manner is a challenge. The required information and relevant knowledge needs to be provided not only in a structured and complete way, but also in a context-specific manner. To investigate some of the underlying research challenges an International Collaborative Research Project to develop mobile based information systems for people in developing countries was launched. User centered Ontology was developed as a part of this project. We developed a new approach to model the domain knowledge to meet particular access requirements of the users in agriculture domain in Sri Lanka. Through this approach, we have investigated how to create a knowledge repository of agricultural information to respond to user queries taking into account the context in which information is needed by them at various stages of the farming life cycle. The Delphi Method, Modified Delphi Method and the OOPS! (web-based tool) were used to validate the quality of the ontology. Initial system was trialed with a group of farmers in Sri Lanka. The online knowledge base with a SPARQL endpoint was created to share and reuse the domain knowledge that can be queried based on user context. A semi-automatic end-to-end ontology management system was developed to manage the developed ontology as well as the knowledge base. It provides the facilities to reuse, share, modify, extend, and prune the ontology components as required.

Keywords— Agricultural Information, Contextual Information, Knowledge Modeling, Ontology, Ontology Management.

I. INTRODUCTION

People in agriculture domain need agricultural information and relevant knowledge to make informed decisions and to satisfy their information needs. For example farmers need information on pest and diseases, control methods, seasonal weather, best varieties or cultivars, seeds, fertilizers and pesticides, etc. to manage their farming activities [1], [2]. Other stakeholders of the domain such as agricultural instructors, researchers, information specialist, etc. need agricultural information to make better decisions. For example, researchers are interested to know the information about how to solve the problems of pest and symptoms of

crop diseases for research purposes, agricultural instructors need domain-specific information to help farmers in their region. Thus, all the stakeholders in the agriculture domain need agricultural information relevant to them to make better decisions, do further research, or analyze the information for future needs and predictions. They can get some of this information from multiple sources such as agricultural websites, agriculture department leaflets and mass media. However this information is general, incomplete, heterogeneous, and not structured to meet their needs. They require information within the context of their specific needs in a structured manner. Such information could make a greater impact on their decision-making process [3].

Not having an agricultural knowledge repository that is consistent, well-defined, and provide a representation of the agricultural information and knowledge needed by the farmers within their own context is a major problem. This problem is not only limited to farmers, it effects every one working in the agriculture domain.

Social Life Networks for the Middle of the Pyramid (www.sln4mop.org) is an International Collaborative research project aiming to develop mobile based information system to support livelihood activities of people in developing countries [4]. The research work presented in this paper is part of the Social Life Network project, aiming to provide information and knowledge to farmers based on their own context in Sri Lanka using a mobile based information system. This system has now been expanded to include everyone working in the agriculture domain in Sri Lanka through a development of an end-to-end ontology management system via web based interface.

To represent the information in context-specific manner, firstly, we need to identify the users' context (i.e. users' context model). Since farmers are the main stakeholders in the domain and other stakeholders are willing to help farmers in various manner, we have identified the users' context specific to the farmers in Sri Lanka such as farm environment, types of farmers, farmers' preferences, and farming stages [5]. The farming stages that we have identified as relating to our application are Crop Selection, Pre-Sowing, Growing, Harvesting, Post-Harvesting, and Selling [5].

Next we have identified an optimum way to organize the information and knowledge in the user context using ontologies. An ontology is an explicit specification of a conceptualization [6]. Mainly due to the complex nature of the relationships among various concepts, attenuate the

incompleteness of the data, and also add semantics and background knowledge about the domain we have selected a logic based ontological approach to create our knowledge repository. We first developed an ontological approach to represent the necessary agricultural information and relevant knowledge within the user context [5]. Using this approach we designed the ontology to include information needs identified for the first stage of farming life cycle [7]. Next we extended the ontology to include events associated with the farming life cycle such as fertilizers, growing problems and their control methods [8]. A revised and enhanced version of the work and an end-to-end system that includes creation of an online knowledge base and an information retrieval interface has been published in [9]. In this paper we have presented the overall development process of the user centered ontology in the domain of agriculture. The user centered ontology was implemented using protégé editor (based on OWL 2-DL). The remainder of the paper is organized as follows. Section 2 summaries overall development process of the ontology. Section 3 concludes the paper and describes the future directions.

II. ONTOLOGY DEVELOPMENT PROCESS

First we have extracted domain specific knowledge using the reliable knowledge sources [1], [2], [10]-[14] based on identified needs of farmers as well as other stakeholders in the agriculture domain. By analyzing information gathered from various sources, we have identified what information is required by the users in agriculture domain at various stages to support better decisions, problem solving, and other information needs. As a result of this analysis, information important to users was identified in the form of questions. Some examples are given in Table I.

TABLE I
USERS' INFORMATION NEEDS

Users' Information Needs
What are the suitable crops to grow?
What are the best varieties (or cultivars)?
What are the best fertilizers for selected crops and in what quantities?
When is the appropriate time to apply fertilizer?
What are the types of pests or crop diseases?
How to solve the problems of pests?
What are the symptoms of crop diseases?
How to solve crop diseases?
Which are the most suitable control methods to a particular disease?
What are the best techniques for harvesting?
What are the crops cultivated by other farmers and in what quantities?

In this study we identified that, *farm environment, types of farmers, farmers' preferences, and farming stages* (referred as user context) are the important factors that need to be considered when delivering agricultural information and knowledge to farmers [5].

A. Users' Information Needs in Context

We identified areas of generic crop knowledge required to answer the users' information needs (see Table I). We have called these broad areas of knowledge as "knowledge modules". The generic crop knowledge consists of modules such as nursery management, harvesting, post-harvesting,

growing problems, control methods, fertilizer, environmental factors, crops and basic characteristics of crops, variety, etc. For example, crop module has information about crops and fertilizer module has fertilizer information and knowledge to handle the fertilizer knowledge needed by users. Next we identified the relationships among them. The Fig. 1 shows the generic crop knowledge module. This modularization also helps us to reduce the complexity of real-world scenario in the application domain.

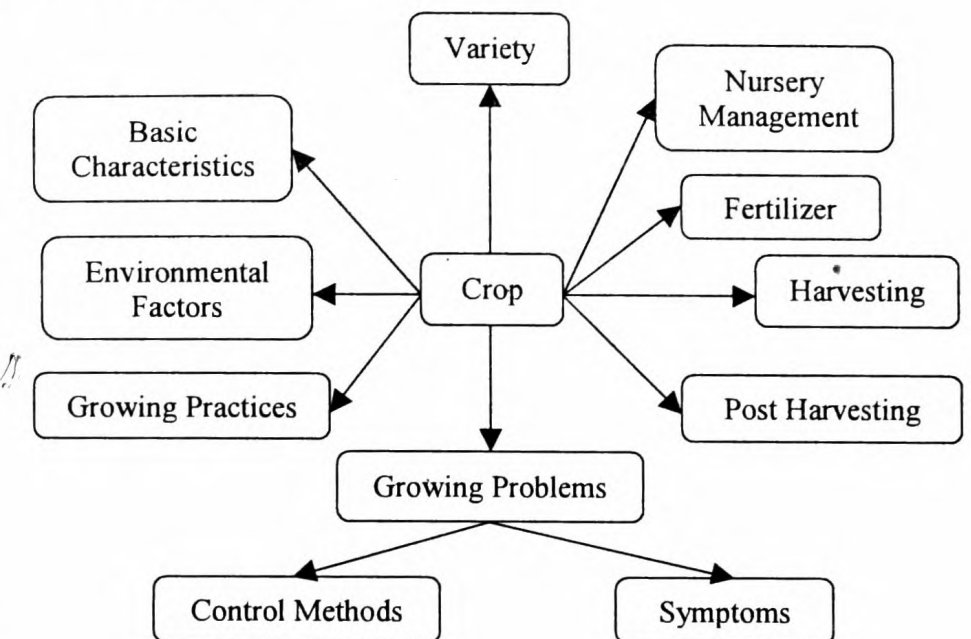


Fig. 1 Generic Crop Knowledge Module

We organized the users' list of information requirements according to the farming life cycle stages. We begin our detail design process with the first question in the list; "*What are the suitable crops to grow?*" Choosing the best crop for individual situations is difficult since one has to consider many factors such as environmental conditions which can vary based on region and time period, preferences of user, and resources available for them for cultivation. We therefore have reviewed existing literature on crop selection to identify a suitable criterion which can be used to make better decisions. Then we summarized the existing criteria and identified a suitable crop selection criterion for our application based on the requirements of agriculture domain in Sri Lanka [9]. It includes the environmental conditions, the special characteristics of a crop, user preferences, about what other farmers grow in different regions and its quantities, and the market information.

In a similar way, we identified the criteria for each item in the list of user information requirements. For example, we defined the criteria for applying fertilizers to deliver fertilizer knowledge and for the growing problems and their control methods related to second stage and third stage of the farming life cycle respectively. When applying a fertilizer for a specific crop user needs to know fertilizer quantity and its unit. A fertilizer quantity depends on many factors; especially it depends on the location, water source, soil Ph range, time of application, application method, and fertilizer type. Thus fertilizer quantity needs to be specified in relation to all these information. To do that, we introduced a new information module; *Fertilizer Event* to represent this additional information and new relationships to describe this event. The details of modeling the events associated with second and third stages of the farming life cycle and the associated challenges are explained in [8].

The next step is formulation of a set of contextualized or personalized information based on the users' information needs. For this we had to develop our own approach to

formulate the contextualized information. With the help of the domain experts we first identified the breadth of information required by users. Next based on earlier identified user context we identified the conditions we can use to obtain a subset of information that can satisfy a specific information need of users. Based on this, we expanded the questions in the user information need list to include the user context.

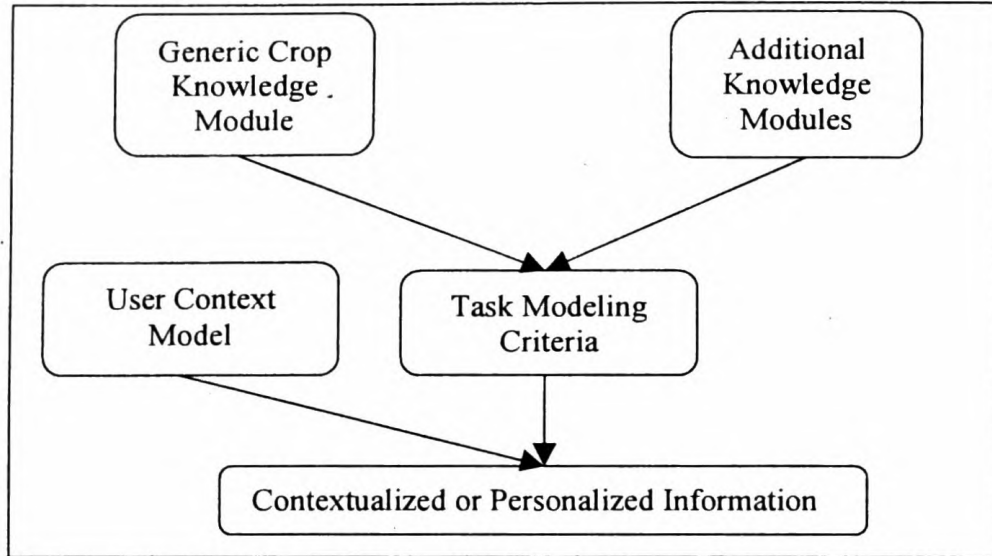


Fig. 2 Basis for Modeling Contextualized Information

The Fig. 2 shows our basis for formulating contextualized information. The formulation of contextualized information for crop selection depends on multiple criteria such as the users' context, general crop knowledge, crop selection criteria (select suitable task modeling criteria; for example criteria for selecting crops, applying fertilizers, selecting control methods, etc.) and the users' constraints. This serves as a basis for formulating information in a user context for our application.

Some examples of contextualized information related to each category of crop selection, fertilizer applying, and control method selection are given in Table II. We have identified the user constraints based on the each criterion factor. We therefore need to select suitable crops based on the different locations, different seasons, different soil factors, etc. or combination of these constraints. We have identified these different constraints related to this application, for example, the location as Zone, Agro Zone, Elevation based location, Province, District, and Regional area. Through this process we have formulated the contextualized questions covering all constraints relevant to each criteria. We also generalized these questions. These are the range of questions that we want to obtain answers by organizing the information and knowledge to query in context using an ontology.

TABLE II
USERS' INFORMATION NEEDS IN CONTEXT

Users' Information Needs	Users' Information Needs in Context	Generalizing Contextualized Information
Stage 1: What are the suitable crops to grow?	<p><i>Suitable crops based on the Environment:</i> What are the suitable vegetable crops for 'UpCountry', applicable to the 'Well-drained Loamy' soil, and average rainfall > 2000 mm?</p> <p><i>Suitable crops based on Preferences of Users:</i> What Brinjal's varieties are good for the</p>	<p>What are the suitable types of crops for specified location (Elevation), applicable to the specified soil types/characteristics, and conditions (Rainfall or Temperature)?</p> <p>What crop's varieties are good for the specified</p>

	<p>'Bacterial Wilt' disease? <i>Suitable crops based on Environment, Preferences and Other Information:</i> What is the best Brinjal's variety which is suitable for 'DryZone' and high-resistance to the 'Bacterial Wilt' disease?</p>	<p>disease? What is the best crop's variety which is suitable for specified location (Climatic Zone) and resistance conditions to the specified disease?</p>
Stage 2: What are the suitable fertilizers for selected crops and in what quantities?	<p><i>Suitable fertilizers based on the Environment:</i> What are the suitable fertilizers and in what quantities for farmers in Badulla district who cultivate Tomatoes? <i>Suitable fertilizers based on Preferences of Users:</i> What are the suitable organic fertilizers which are used to Basal dressing for Tomato?</p>	<p>What are the suitable fertilizers and in what quantities for farmers in specified location (Districts) who cultivate specified crops? What are the suitable types of fertilizers which are based on method of application for specified crops?</p>
Stage 3: Which are the most suitable control methods to a particular disease?	<p><i>Suitable control methods based on the Environment:</i> What are the suitable control methods to control weed for Radish which is grown in Up Country? <i>Suitable control methods based on Preferences of Users:</i> What are the suitable chemical control methods and in what quantities to control Damping-off for Tomato? <i>Suitable control methods based on the Farming Stages:</i> What are the suitable control methods to control Bacterial wilt for Brinjal before infestation of the disease?</p>	<p>What are the suitable control methods for different types of growing problems to specified crop which are grown in specified location? What are the different types of control methods to specified growing problem of a crop? What is the suitable control method based on the specified farming stages to specified growing problem of a crop?</p>

B. Representation of Contextualized Information

An ontology provides a structured view of the domain knowledge and act as a repository of concepts in the domain. This structured view is essential to facilitate knowledge sharing, knowledge aggregation, information retrieval, and question answering [15]. We therefore use an ontological approach to represent the contextualized knowledge that can be used to find a response to queries within a specified context in agriculture domain.

We reviewed ontology development methodologies and techniques to identify a suitable ontology development approach. Grüniger and Fox [16] have published a formal approach to design ontology while providing a framework for evaluating the adequacy of the developed ontology. We therefore selected Grüniger and Fox's methodology, a logic based approach to develop a user centric ontology for agriculture domain.

Our ontology creation begins with the definition of a set of users' information needs identified in Table I. We take these

information needs as the main motivation scenario of our application to provide information in context. Competency questions (CQs) determine the scope of the ontology and use to identify the contents of the ontology. The ontology should be able to represent the CQs using its terminologies, axioms and definitions. Then, a knowledge base based on the ontology can provide answers to these questions [16]. Therefore, formulation of the CQs is a very important step because these questions guide the development of the ontology. In our application, the contextualized information (see Table II) has been used as the CQs to develop the ontology because it satisfies the expressiveness and reasoning requirements of the ontology.

The implemented ontology using protégé is available at http://www.sln4mop.org/ontologies/2014/SLN_Ontology. It consists of 84 concepts, 192 object properties, and 45 data properties. Currently it has 23 vegetable crops, 8 fertilizers, 9 diseases, and 20 pesticide instances. The more details of the ontology development are explained in [9].

Fig. 3 shows the part of implemented ontology using Cmap tool. The Cmap (Concept Map) tool is used to view the graphical representation of the ontology for better user understanding.

C. Generalizing Approach

We have generalized the specific approach that was developed to create the user centered ontology for Social Life Networks. The Fig. 4 shows this generalized approach. According to this approach, we first identify a set of questions (Users' Information Needs) that reflect various motivation scenarios. Next we create a model to represent information in user context. Then we derive the contextualized information incorporating user context and task modeling with generic knowledge module. We refer to this contextualized information (refer Table II.) as the informal CQs. These CQs are used to identify the ontology components according to the Grüninger and Fox's methodology to develop the ontology.

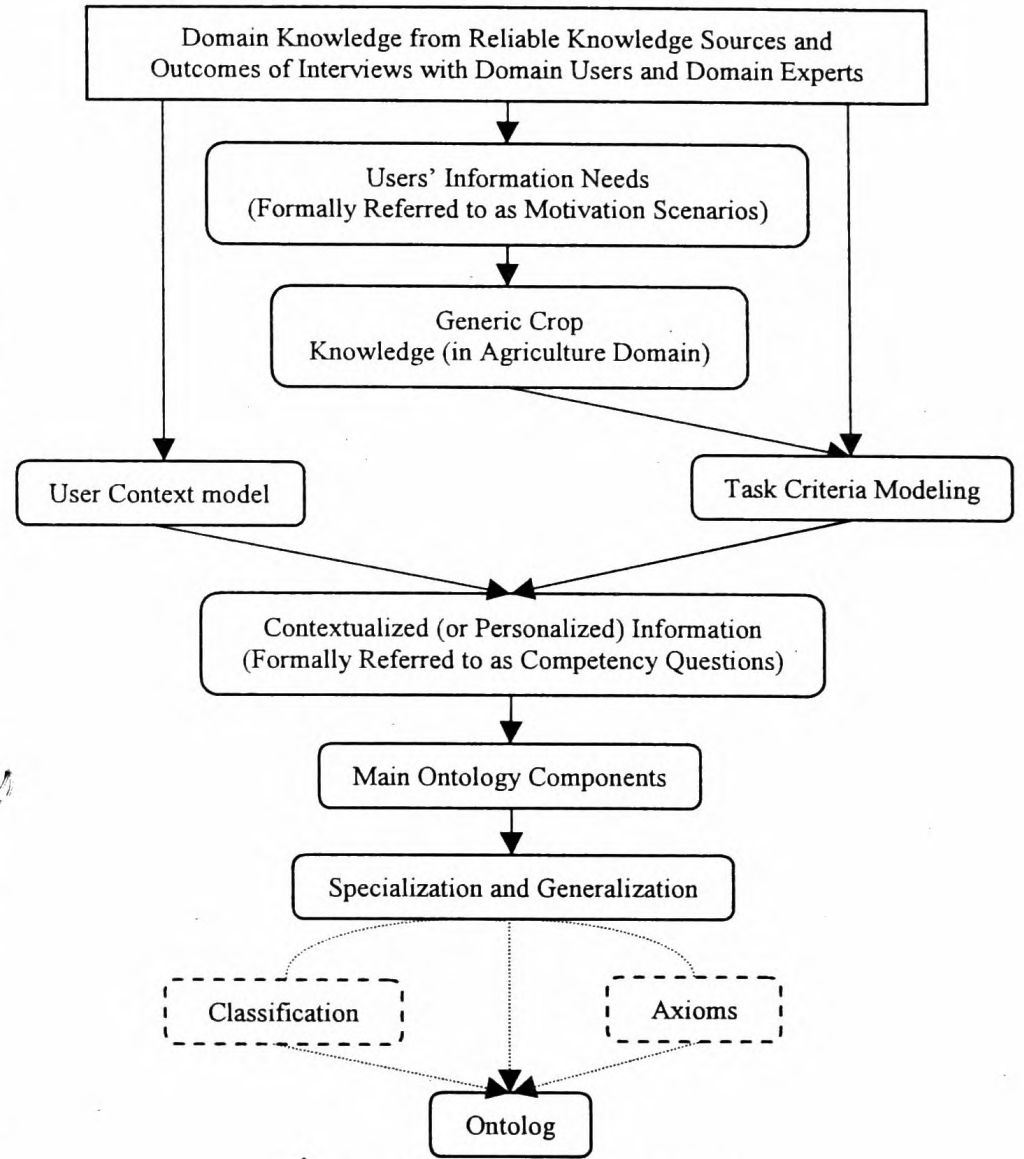


Fig. 4 Ontology Design Framework

Using this framework, we can extend the ontology for different scenario problems. For example, when answering scenario question like "How to solve the growing problems such as diseases, weeds, or pests?" we need to take into account suitable criteria for selecting control methods and users' context. We can then formulate the contextualized information based on this systematic approach. These questions drive the development of the ontology and can represent contextual information to satisfy the user needs.

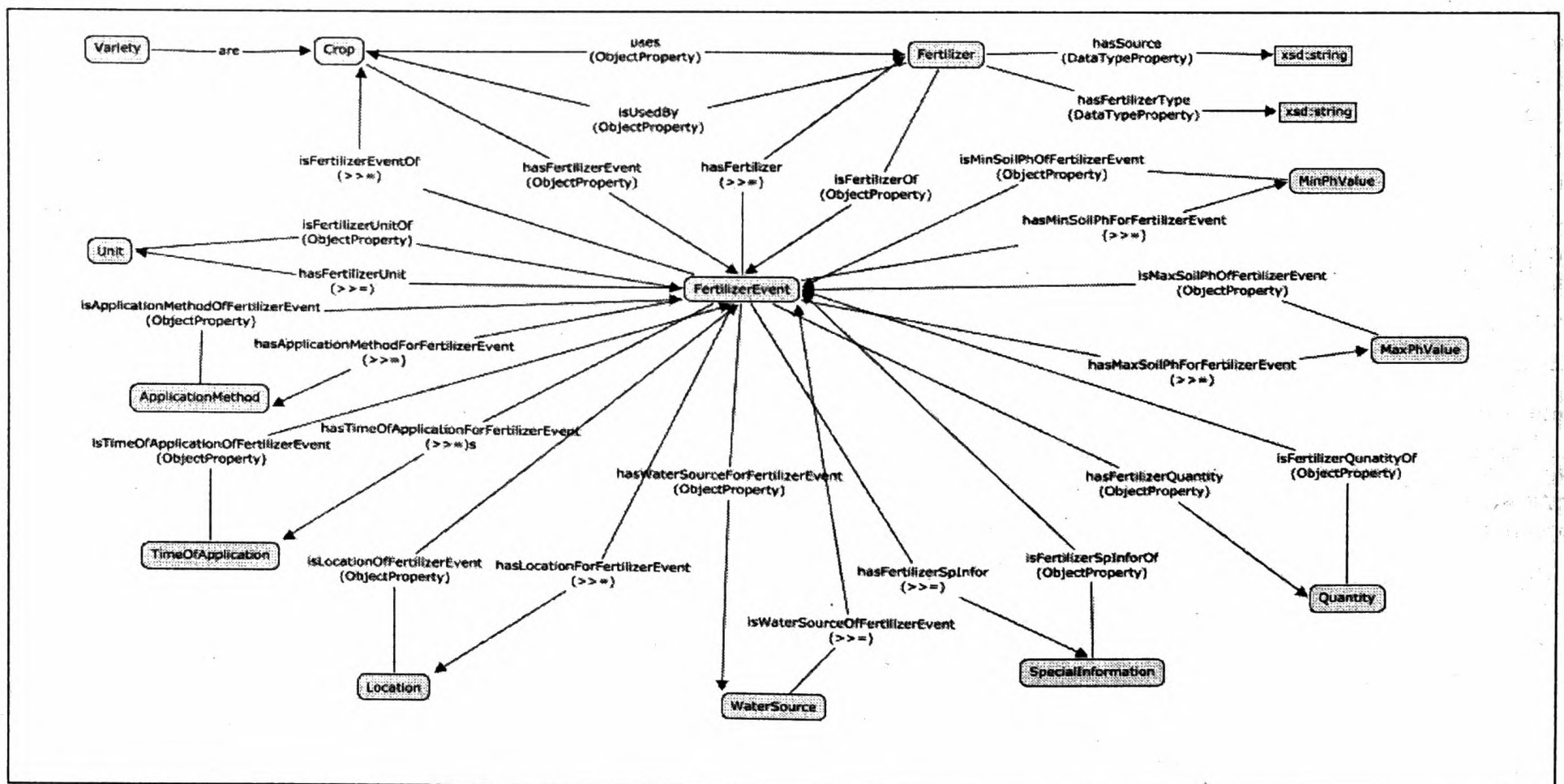


Fig. 3 Part of the Ontology Structure using Cmap

D. Validation, Evaluation and Maintenance of the Ontology

It is very important to check the validity of the ontology. In this study, the correctness of the contents and correctness of the construction of the ontology have been validated.

The content correctness depends on definitions of concepts, relationships between concepts, hierarchical structures, concept properties, and information constraints of the ontology. The Delphi Method is a research technique that is used to obtain the responses to a problem from a group of domain experts [17]. We selected the Delphi method to obtain expert advice and responses to check the definitions of concepts, relationships, and data properties; and hierarchical structures. The modified Delphi method can be adapted to use in face-to-face group meetings, allowing group discussions. As we need to make more dialogues and collaboration between participants to make judgments to the criteria and assumptions we made, we use the modified Delphi method to validate design criteria and assumptions made during the design process. The validation process is done by agricultural experts by examining the correctness, relevancy and consistency of the ontology components and a set of predefined criteria. The contents have been refined based on domain experts' feedbacks and comments.

One approach for checking the correctness of the construction is to analyze whether the ontology contain anomalies or pitfalls [18]. We first identified the common pitfalls before the implementation. Next we identified the types of Ontology Design Patterns (ODPs) that helps to avoid the pitfalls by means of adapting or combining existing ODPs [18]. Design patterns are shared guidelines that help to solve design problems, for example Semantic Web Best Practices and Development under W3C [19]. We also used the web-based tool called OOPS! [18] to detect potential pitfalls in the ontology. Using above methods we validated the accuracy and the quality of our ontology.

The implemented ontology using protégé is used to evaluate the ontological commitments internally and also used to test the consistency and inferences using reasoners. We used the CQs to evaluate the ontological commitments to see whether the ontology meets the users' requirements using Description Logic (DL) queries and SPARQL queries [9].

Next we checked the user satisfaction of our ontology. We used a mobile based application for this evaluation. A Mobile based application was developed to provide information by using this ontology [20]. The first evaluation was done only for crop selection with a group of 32 farmers in Sri Lanka [20]. We have gathered suggestions from farmers and other stakeholders of the domain for our future designs.

The Knowledge Base based on the ontology was created by populating the ontology with instances to share and reuse the agricultural information via the Web [9]. The online knowledge base can also be used for evaluation process. We can query the contextualized information on the Web via this application (SPARQL endpoint) using SPARQL queries (refer <http://webe2.scem.uws.edu.au/arc2/select.php>). This application specially is useful for agricultural instructors, researchers, and people at the Department of Agriculture to find information based on their needs. For example, the following SPARQL query lists the best Brinjal's varieties which are suitable for 'DryZone' and high-resistance to the 'Bacterial Wilt' disease? We evaluated the ontology by evaluating outputs of the queries.

```
PREFIX sln:
<http://www.sln4mop.org/ontologies/2014/S
LN_Ontology#>
SELECT ?Variety WHERE {
{?Variety sln:isVarietyOf sln:Brinjal}
{?Variety
sln:hasDiseaseResistanceEvent ?s}
{?s sln:hasDiseaseResistanceRate sln:High}
{?s sln:hasResistanceDisease
sln:Bacterial_Wilt}
{?Variety sln:growsIn sln:DryZone}}
LIMIT 250
```

Ontology building is a significant challenge for a number of reasons, for example it takes a considerable amount of time and effort to construct an ontology, it requires a sophisticated understanding of the subject domain, and also it is even greater challenge if the ontology developer or engineer is not familiar with the domain of interest. Therefore it is very important to be able to maintain the developed ontology by updating the content (i.e. extending the ontological structure and modifying the instances) of the ontology on an ongoing basis.

A community based facility to manage the structure of the developed ontology in the long term as well as further populate the knowledge base is very useful. For this we have developed an end-to-end semi-automatic collaborative ontology management system for large-scale development and maintenance purposes by giving facilities to reuse, modify, extend, and prune the ontology components as required. It also has facilities to capture users' information needs and their context, as well as search domain information in user context.

From this system we can populate the ontology with instances by involving people (agricultural instructors and researchers) in agriculture community. We also can modify the structure of the ontology from getting the knowledge of the agriculture domain experts and receiving the information needs of all the stakeholders working in this domain. Ontology development is a community activity. For example, to fully populate the ontology with the real data, we developed a semi-automated system to capture this information via relational databases. For that we have used a framework called "CBEADS": Component Based Ebusiness Application Development and Deployment Shell [21] as a data capturing application (see interface in Fig. 5).

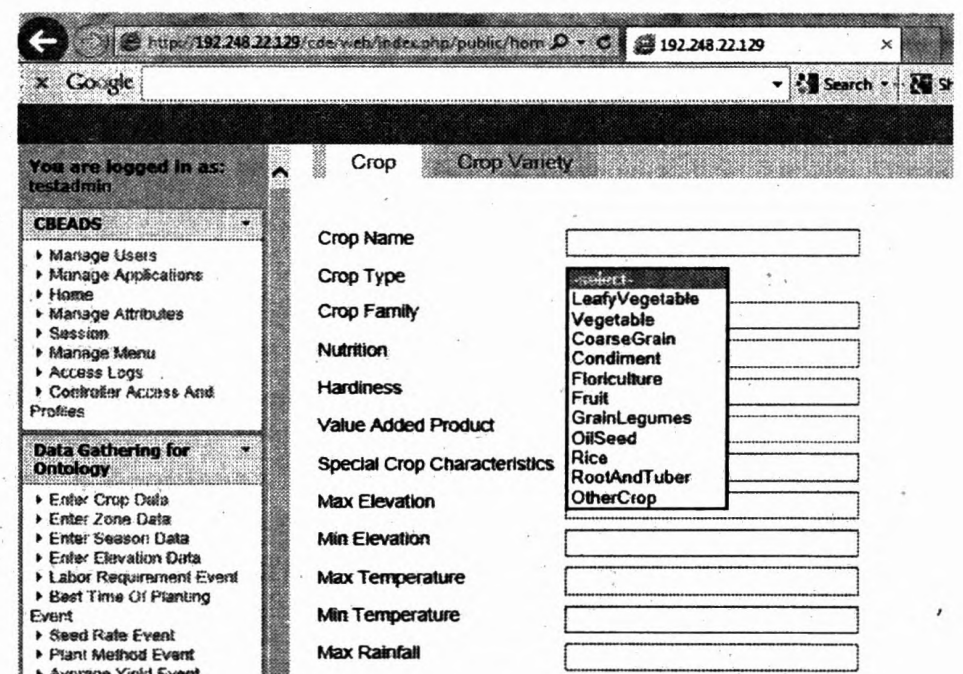


Fig. 5 Web based Interface for Capturing Instances

The details of design and development of the end-to-end ontology management system is outside the scope of this paper.

The Fig. 6 shows the overall development process of the ontology. It is an iterative process. Based on the results and feedbacks of the validation and evaluation processes the design of the ontology is refined using the design framework shown in Fig. 4. Then the ontology can be expanded using the web based ontology management system by modifying the ontology.

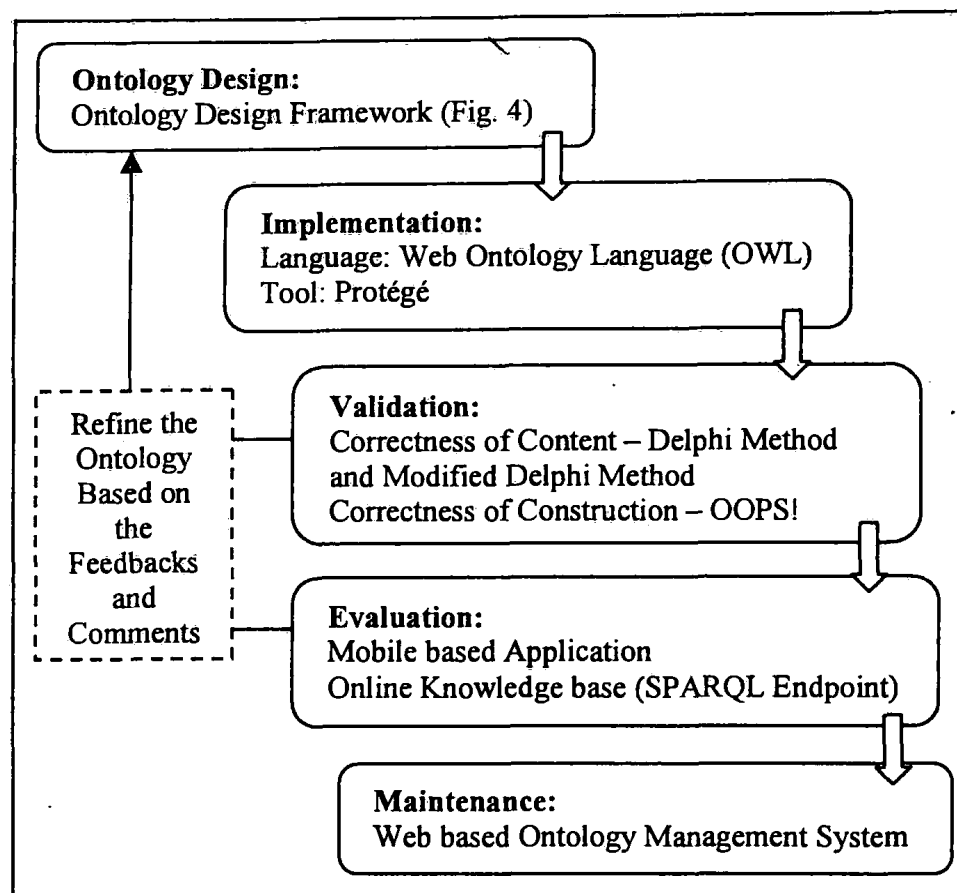


Fig. 6 Overall Development Process of the Ontology

III. CONCLUSIONS

People in agriculture domain in Sri Lanka need necessary and relevant information to make optimal decisions for successful farming or/and enhance the farming industry. Currently, not having agricultural knowledge repositories that can be easily accessed by people in agriculture within their context is a major problem. In this research project we have addressed this need.

In this study, we identified the user context related to the farmers in Sri Lanka. Next we developed a logic based ontological approach to meet the information needs to suite the identified context. We have achieved this by modifying how contextualized information is formulated in a well-established methodology.

In this paper we have summarized the overall ontology development process to organize domain knowledge by meeting particular access requirements effectively using the framework shown in Fig. 6. We validated the ontology in terms of accuracy and quality. We evaluated the ontology against the user requirements. The online knowledge base with a SPARQL end-point to share and reuse the domain knowledge was created. To fully populate the knowledge base as well as modify the ontology we developed a semi-automatic end-to-end ontology management system that will help us to develop and manage complex real-world application based ontologies in the long term as a collaborative process.

We received very valuable feedback from the field trials. Based on this feedback we are now refining the application.

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