Designing a Farmer Centred Ontology for Social Life Network

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Abstract: Rapid adoption of mobile phones has vastly improved access to information. Yet finding the information within the context in which information is required in a timely manner is a challenge. To investigate some of the underlying farmer centric research challenges a large International Collaborative Research Project to develop mobile based information systems for people in developing countries has been launched. One major sub project is to develop a Social Life Network; a mobile based information system for farmers in Sri Lanka. Lack of timely information with respect to their preferences and needs to support farming activities is creating many problems for farmers in Sri Lanka. For instance, farmers need agricultural information within the context of location of their farm land, their economic condition, their interest and beliefs, and available agricultural equipment. As a part of this project we investigated how we can create a knowledge repository of agricultural information to respond to user queries taking into account the context in which the information is needed. Because of the complex nature of the relationships among various concepts we selected an ontological approach that supports first order logic to create the knowledge repository. We first identified set of questions that reflect various motivation scenarios. Next we created a model to represent user context. Then we developed a novel approach to derive the competency questions incorporating user context. These competency questions were used to identify the concepts, relationships and axioms to develop the ontology. Initial system was trialled with a group of farmers in Sri Lanka. There was universal agreement among the farmers participated in the field trial to varying degree (strongly agree, agree, moderately agree) to the question "All information for the crop selection stage is provided".

1 INTRODUCTION

From time to time farmers need information such as seasonal weather, best cultivars and seeds, fertilizes, information on pest and diseases, control methods, harvesting and post harvesting methods, accurate market prices, and current supply and demand to make informed decisions at various stages of the farming lifecycle (De Silva et al., 2012; Lokanathan and Kapugama, 2012). Some of this information is available from government websites, leaflets and mass media. Farmers require this information within the context of their specific needs. Such information could make a greater impact on their decision-making process (Glendenning et al., 2010).

Not having an agricultural knowledge repository that can be easily accessed by farmers within their own context is a major problem.

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.

The research work presented in this paper is part of the Social Life Network project, aiming to provide information to farmers based on their context. For this we had to develop a knowledge repository. Because of the complex nature of the relationships among various concepts we selected an ontological approach to create the knowledge repository.

To represent the information in context-specific manner, firstly, we need to identify farmers' context related to this application. We identified the context specific to the farmers in Sri Lanka (i.e. *farmers' context*) by analyzing information gathered from various reliable knowledge sources. The Table 1 shows the farmers' context that was identified related to this application. The way of modeling the farmers' context and the farming stages related to

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this application is outside the scope of this paper and it is explain in (Walisadeera et al., 2013).

Table 1: Farmers' Context.

Farmers' Context	Description
Farm environment	Information about environment based on location of farm such as elevation, rainfall, climate zone, temperature, humidity, sunlight, wind, soil, etc.
Types of farmers	Farmers are classified based on size of the cultivated farm land and estimated budget for cultivation. There are two main categories; garden farmers and commercial farmers. Commercial farmers can be further categorized as small-scale farmers, medium-scale farmers and large-scale farmers.
Preferences of farmer	Farmers have their own preferences such as high yielding varieties, preferred control methods and fertilizers, low labour cost crops, high disease and insect resistance crops, desired farming systems and techniques, etc.
Farming stages	Required information varies based on different stages of the farming lifecycle. To improve overall decision making in farming, we have defined six farming stages covering all required information needed by farmers (refer Table 2 for farming stages).

Recently, ontologies have emerged as a major research topic in Information Systems. The term 'ontology' originated from philosophy and it is concerned with the study of being or existence (Rumbaugh et al., 1991). Lately, it has been used in computer science and information science, for knowledge engineering, databases and software engineering purposes to define models that specify reusable components and the relationships among them. Ontologies are widely used for different purposes (e.g. natural language processing, knowledge management, e-commerce, intelligent integration of information and semantic web) in different communities (e.g. knowledge engineering and databases).

An Ontology provides a structured view of domain knowledge and act as a repository of concepts in the domain. This structured view is essential to facilitate knowledge sharing, knowledge

Table 2: Farming Stages.

Farming Stages	Description
Crop Selection	Most important decision is *deciding which crops to grow*. Crop selection is a complex process because it depends on many factors. The environmental factors mostly affected this selection. Features of a crop, farmer preferences, available resources and market demand are other key determinant for this decision.
Pre-Sowing	Refers to *preparing the field* for selected crops. At this stage farmer needs information on quality agricultural inputs such as seed rate, plant nutrients and fertilizing, irrigation facilities and new techniques for field preparation.
Growing	Includes information related to *managing the crop through its growing stages*. Information on planting methods, good agriculture practices (traditional and new technology), common growing problems and their management is required in this stage.
Harvesting	At this stage farmer needs information related to *harvesting* such as maturity time, methods and techniques of harvesting, expected average yield, labour cost and total production cost for cultivation.
Post-Harvesting	Refers to proper *handling after harvesting*. Required information includes post harvesting issues and management, packing, grading, storing, standardization, transportation and value added products.
Selling	Refers to *preparation for selling*. Mainly includes information related to the market such as market prices, consumer behaviour and demand, and alternative marketing channels.

aggregation, information retrieval and question answering (Gruber, 1995). In addition, ontology provides the means of deduction capabilities provided by an inference mechanism and reasoning support in order to generate further knowledge (i.e. not explicitly known but can be deduced based on the existing knowledge of the domain) (Fox et al., 1996). Thus, ontology represents a better data model (richer knowledge) than a normal data model. Therefore, ontology can be used to find a response to queries within a specified context in the domain of agriculture. The most quoted definition of ontology was proposed by Thomas Gruber as *"an ontology is an explicit specification of a conceptualization*" (Gruber, 1993). This definition is adapted for our ontology.

The existing ontologies in the domain of agriculture for example Thai Rice Ontology (Thunkijjanukij, 2009) are crop-specific thus too general and not specific enough to satisfy the farmers' needs for timely information in context.

To develop an ontology we need to carefully identify suitable ontology development methodology because there are several methodologies and techniques for building ontologies reported in the literature (Fernández-López and Gómez-Pérez, 2002). We select a first-order logic based approach; *Grüninger and Fox's methodology* (Grüninger and Fox, 1995), to develop our ontology because its expressiveness helps us to represent information in context. Furthermore, this methodology provides a formal approach to design ontology as well as a framework for evaluating the adequacy of the developed ontology. Its main strength is high degree of formality and focuses on building ontology based on First-Order Logic (FOL) by providing strong semantics.

Since there is no technique for formulating the competency questions incorporating user context, we have an issue with regarding to correctness of the contents of the ontology. Therefore, the main contribution of this paper is a novel approach to derive the competency questions incorporating user context. We also introduce a framework for ontology design that we developed to design the ontology for farmers to represent the necessary agricultural information and knowledge within the farmers' context.

The rest of the paper is organized as follows. Section 2 describes the design of the ontology for the crop selection stage. This design process, also includes a systematic approach to generate the competency questions. In section 3 we present a genaralisation of the approach that evolved from this work. The section 4 provides a summary of initial field trial used to test the ontology for crop selection phase. In section 5 we conclude the paper with a summary and describe the future direction.

2 DESIGN OF THE ONTOLOGY

In this section we describe the process that we used to design the agricultural ontology for farmers. Our ontology creation begins with the definition of a set of farmers' problems identified by reviewing related literature in the domain of agriculture (Decoteau, 2000; Kawtrakul, 2012; Babu et al., 2012) and the outcomes of the interviews with Sri Lankan farmers and agricultural specialists. We generalize these problems and organize these according to the farming lifecycle stages (see Table 2). We take these real farmers' problems as a motivation scenario of our application to provide information in context (see Table 3).

Table 3: Real-World Application Scenario.

- What are the suitable crops to grow?
- What are the best 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 protect crops from disease?
- Which are the most suitable control methods to a particular disease?
- What are the symptoms of a specific disease?
- What are the most important factors to maintain quality of harvested crops?
- Which post-harvest method is best for a particular crop?
- What are the crops cultivated by other farmers and in what amounts?

Next we identify areas of generic crop knowledge required to answer these motivation scenario questions. These broad areas of knowledge we term as knowledge modules. The generic crop knowledge consist of modules such as nursery management, harvesting, post-harvesting, growing problems, control methods, fertilizer, environmental factors and basic characteristics of crops. A cultivar (variety) is a group of crops that share common qualities of crops of the same species (Decoteau, 2000). Each information module has related information to answer the scenario questions. For example, crop information module has information about crops and cultivars. Next we identify relationships among them. The following Figure 1 shows the generic crop knowledge module. To represent agricultural knowledge within the farmer's context we need to associate this generic crop knowledge with characteristics that describes the farmers' context.

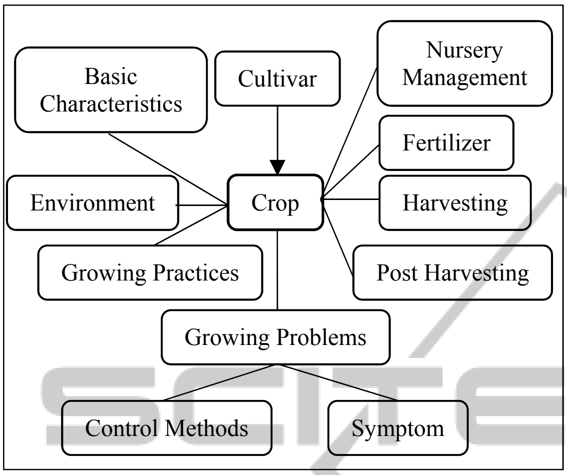

Figure 1: Generic Crop Knowledge Module.

We begin our detail design process with first question of the motivation scenario "*What are the suitable crops to grow?*" Selecting proper crops and cultivars is paramount for successful farming. During initial interviews with vegetable farmers they also identified this as a very important question. 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 farmer and resources available for them for cultivation. We have reviewed existing literature on crop selection criteria to identify a suitable criterion which can be used to assist farmers to make better decisions.

According to the Decoteau's (2000), the crop selection especially for vegetable crops depends on four considerations; Crop Consideration, Farmer Consideration, Labour Consideration and Marketing Consideration. This criterion is designed only for vegetable crops and for farmers in developed countries. Therefore this criterion is not a good fit for our application.

Bareja (2012) has identified following as major crop selection factors for successful farming; Farm conditions (an environmental scanning should be conducted first), Crop or varieties adaptability (crops and varieties should be selected based on adaptability to farm conditions), Available technology, Marketability and profitability, Resistance to pests and diseases, Farming systems and Security (crop selection may be done in favour of security such as absence of security personnel). This criterion is designed for multiple crops and cultivars selection. However, it has not considered the important factors such as labour cost and the farmer types.

We next reviewed factors described in the NAVAGOVIYA (CIC, 2012) web site which is one of the important web sources in the domain of agriculture in Sri Lanka for selecting suitable crops. These factors are Climatic requirements, Soil properties, Growing season, Labour availability and cost, Raw material availability and Market demand.

According to the above analysis, environmental condition has been identified as a most important factor. Therefore, in our application, the environmental conditions were given the first priority. Also these conditions cannot be controlled by the farmers. Next from the crops that meet the environmental conditions farmers can choose the best cultivars by considering factors such as high yielding cultivars, the special characteristics of a crop (e.g. colour, size, shape, flavour, hardiness, nutritional quality, etc.), maturity and disease resistance (Decoteau, 2000). These factors come under farmer consideration because farmer can decide importance of each of the factors according to their interests. Based on various crop selection criteria reviewed earlier we can see that only a few preferences have been considered. However, in our application we have included wide range of preferences because this will help farmers to make better decisions.

According to the collected information through interviews with farmers and agricultural specialist in Sri Lanka, information about what other farmers grow in different regions and its quantities is also an important factor when selecting crops because from this information farmers can get an idea about whether there is going to be an oversupply or not. Farmers also consider the market information when selecting crops; therefore, we take the market information as a final consideration of our crop selection criteria.

Finally farmers select the suitable crops and cultivars by considering all the necessary factors according to their own context. The following Table 4 provides a summary of the crop selection criteria reviewed earlier.

We have defined a crop selection module (see Figure 2) based on our crop selection criteria to deliver information and knowledge related to crop selection stage based on information needs of the farmers. Environment, Crop, Cultivar and Basic Characteristics are the same information modules

Table 4: Summary of Crop Selection Criteria.

Criteria (Factors)	Different Sources			
	Decoteau (2000)	Bareja (2012)	CIC (2012)	Our Criteria
Environment	√	√	√	√
Farmer types	√	×	×	√
Labour	√	×	√	√
Crop Characteristics	√	×	×	√
Market	√	√	√	√
Farmer Preferences	limited range	limited range	limited range	wide range
Security	×	√	×	×
Other farmers' information	×	×	×	√

identified in generic crop knowledge module. The information modules such as Farmer, Farmer Types, Preferences and Market are additional information modules needed for the crop selection.

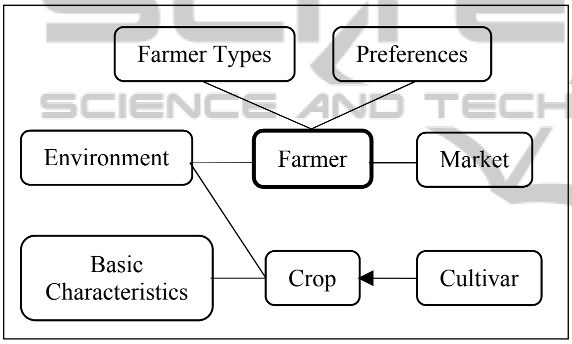

Figure 2: Crop Selection Module.

In this module, we can notice that the farmer is the central concept and this very much motivated us in selecting a farmer centred approach to develop our ontology. Since a cultivar (variety) is a group of crops that share common qualities, we have identified a cultivar as a subset of a crop (i.e. a cultivar is a crop). Types of farmers are classified based on size of the cultivated farm land and estimated budget for cultivation. In here environment is designed with regard to farm environment and crop environment. In this stage we do not consider market information as a factor of crop selection because our initial efforts have focused only on the static information. Static information represents data that rarely change over time while dynamic information such as market prices changes frequently and hard to obtain without an elaborate network to gather market data in real time.

The next step is formulation of a set of informal competency questions based on the motivation scenarios. Competency questions determine the scope of the ontology and use to identify the contents of the ontology. The ontology should be able to represent the competency questions using its terminologies, axioms and definitions. Then, knowledge-base based on the ontology should be able to answer these questions (Grüninger and Fox, 1995). These questions are benchmarks in the sense that the ontology is necessary and sufficient to satisfy the requirements specified by the competency questions (Fox et al., 1996). Therefore, formulation of the competency questions is a very important step because these questions guide the development of the ontology. Also as indicated in Fernández-López (1999), the techniques for formulating the competency questions are not mentioned in the Grüninger and Fox's methodology. We therefore have reviewed the literature to search whether there is a method to formulate the competency questions of an ontology.

Fernandes, Guizzardi and Guizzzardi (2011) have suggested to apply the Tropos methodology (Bresciani et al., 2004) to formulate the competency questions. Tropos is an agent-oriented software engineering methodology. According to the proposed approach competency questions are defined to accomplish the goals of the actor. Systematic analysis of the goals leads to the understanding what are the objectives involved in an organizational environment. To satisfy these goals, the right kind of information is needed, thus, the competency questions are defined based on this information need. Since proposed approach is agent-oriented, it deals with establishing the needs of stakeholders that are to be solved by software. Therefore, this approach is not suitable for our application to model the competency questions.

Thus we had to develop our own approach to formulate the competency questions. With the help of the domain experts we first identified the breadth of information required by farmers. Next based on earlier identified user context what conditions we can use to obtain a subset of information that can satisfy a specific information need of users. Then, we generate the competency questions on the above basis as follows:

- covering all information of the farming stages (e.g. crop selection to selling stage) and its constraints (restrictions) – *it represents the knowledge needed by the farmers*
- farmers' conditions based on the farmers' context (e.g. farm environment, farmer types, farmer preferences and farming stages) – *it provides information in context.*

As an example, the Figure 3 shows our basis for formulating competency questions for crop selection stage.

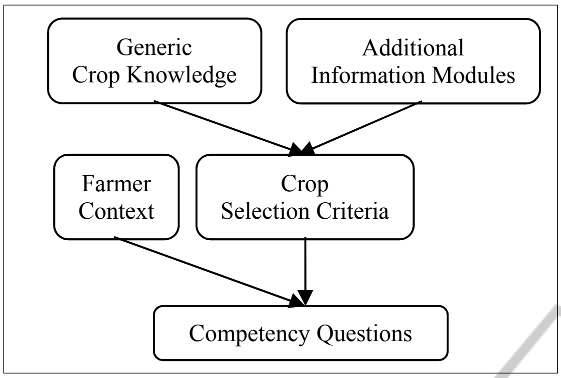

Figure 3: Basis of Modelling Competency Questions.

On this basis, formulation of competency questions for crop selection depends on multiple criteria such as the farmers' context, general crop knowledge, crop selection criteria and the farmers' constraints. This serves as a basis for formulating the competency questions in a user context because it satisfies the expressiveness and reasoning requirements of the ontology. Some examples for competency questions related to each category of crop selection are given in Table 5.

Table 5: Competency Questions for Crop Selection Stage.

Suitable crops based on the Environment:
• Which crops are suitable to grow in the 'LowCountryDryZone' agro-ecology region?
• Which crop's cultivars are the most appropriate for 'WetZone' and 'Maha' season?
• What are the suitable vegetable crops for 'UpCountry', applicable to the 'Well-drained Loamy' soil, and average rainfall > 2000 mm?
Suitable crops based on Preferences of Farmers:
• What are the crops involving in high labour cost?
• What Brinjal's cultivars are good for the 'Bacterial Wilt' disease?
• What are the crops with high resistance to a drought?
Suitable crops based on Farmer related Information:
• Which crops have been cultivated by vegetable farmers and which quantities?
• What is the expected average yield of each farmer?
• How many farmers are involving in vegetable farming in 'UpCountryWetZone' zone and 'Maha' season?
Suitable crops based on Environment, Preferences and Other Information:
• What is the best Brinjal's cultivar which is suitable for 'DryZone' and high-resistance to the 'Bacterial Wilt' disease?

Note that, when we are providing specific answers to the questions, additional information related to the questions can be provided to the farmers. For example necessary environmental conditions which are relevant to crops, because this additional information will also affect their decision-making process (especially crop selection, applying control methods and fertilizing).

In order to answer these competency questions, we need to identify the ontology components. There are three main ontology components; concepts, relationships and constraints. *Concepts* are classes, entities, sets, collections that represent ideas about physical or abstract concepts that constitute a domain. *Relationships* specify the interaction among concepts. *Constraints* capture additional knowledge about the domain and it can be represented as axioms (logical expressions that are always true).

In our ontology design, we use the middle-out strategy to identify the main concepts (Uschold and Gruninger, 1996). The main advantage of this approach is that it starts with most important concepts first. Once the higher level concepts are defined the specialized and generalized hierarchies get identified. Thus, these concepts are more likely to be stable. This results in less re-work and less overall effort.

There are few concepts which we can directly elicit, for instance, we have identified *Farmer* as a main concept of our ontology based on scope of the ontology (i.e. represent agricultural knowledge for farmers). We also identified *Crop* as a major concept of this application. Next, we need to identify other major concepts by analysing each competency question.

For example: *Which crops are suitable to grow in the 'LowCountryDryZone' agro-ecology region?*

The main concept of this query is *Zone*. Then we need to define specialized and generalized (if necessary) hierarchies based on the following criteria:

- concept properties,
- nature of the instances (instances are used for denoting specific members of a concept and represented by constants or variables),
- generic crop knowledge structure, and
- the farmers' context.

To represent the information in context we need to identify the details of each concept in multiple levels. Therefore, designing this type of ontology is an extremely complex task. It needs to be done in a very systematic way.

The concept *Zone* has properties such as *maximum rainfall* and *minimum rainfall*. By specializing *Zone* concept we have defined the concept *AgroZone* (agro-ecology zone) as a subclass of *Zone*, because there are several additional properties specific to *AgroZone* such as maximum and minimum temperature, and maximum and minimum elevation. The properties of concept Zone can be inherited by the AgroZone concept because of the taxonomic hierarchy (is_a). AgroZone is a subclass of Zone if and only if every instance of AgroZone is also an instance of Zone.

Based on the definition of concept Zone (see Table 8), we can categorize the instances as DryZone, IntermediateZone and WetZone if there is no further categorization (has only first level categorization). To reduce complexity of the design of the ontology, we restrict first level categorization as a property of a concept (e.g. *ConceptType*). Then Zone concept has three properties such as ZoneType, maximum and minimum rainfall. In the same manner, crops can be categorized based on the types of crops such as vegetable, fruit, spices, onion, chilly and a number of other tuber crops, grains, etc. We define CropType as a property of a Crop. The Table 6 shows few concepts and their properties related to the crop selection stage.

Table 6: Concepts, Sub-concepts and Properties related to Crop Selection.

Concept	**Properties**
Zone	ZoneType, MinimumRainfall, MaximumRainfall
AgroZone	MaximumElevation, MinimumElevation, MaximumTemperature, MinimumTemperature
Elevation	ElevationType, MaximumElevation, MinimumElevation
Season	StartMonth, EndMonth
SoilType	PhValue, Moisture, Nutrition, Texture, Drainage, EdaphicProblem
Crop	CropType, Hardiness, Nutrition, SpecialCharacteristics
Cultivar	Length, Colour, Shape, Flavour, Size, Quality, Weight, DiseaseResistance, DiseaseResistanceRate, DroughtResistance, DroughtResistanceRate
Farmer	SizeOfFarmLand, BudgetForCultivation, MaxWorkers
Fertilizer	FertilizerType, TimeOfApplication, Source, ApplicationMethod, Quantity, Cost
ControlMethod	MethodType, ApplicationMethod, Source, TimeOfApplication, Quantity, Cost

In farmer-centric view, farmers need to retrieve the agricultural information with respect to their preferences, needs and their situation. Here farmer can be grouped into two main categories such as garden farmers and commercial farmers based on size of the cultivated farm land and estimated budget for cultivation. Commercial farmers can be further categorised as small-scale farmers, medium-scale farmers and large-scale farmers. Since there is a more than one level categorisation, we have organised this categorisation as a taxonomic organisation (e.g. is_a relation not as a *ConceptType*).

The associative relationships (non-taxonomic) are specified as follows:

- identify the concepts and relationships with meaningful relations,
- define the relationships and its inverse relationships (if applicable).

For example, there is an associative relationship with inverse relationship between Crop and Cultivar: Crop *hasCultivar* Cultivar, Cultivar *isCultivarOf* Crop (see Figure 4). The Table 7 shows some relationships including associative relationships with inverse.

Table 7: Associative Relationships with Inverse.

Concept	**Relationship**	**Concept**
Crop	hasCultivar, isCultivarOf	Cultivar
Disease	hasSymptom, isSymptomOf	Symptom
Crop	isAffectedBy , affects	Disease
Disease	isCausedBy, causes	Cause
Disease	isControlledBy, controls	Dise.ConMethod
Farmer	cultivates, isCultivatedBy	Crop

Based on our analysis, Crop has main properties such as Crop Type, Hardiness, Nutrition and Special Characteristics. Since Cultivar is a subclass of Crop these properties can be inherited. Other than these properties Cultivars has properties such as Length, Colour, Shape, Flavour, Size, Quality, Weight, Disease Resistance and its Resistance Rate, and Drought Resistance and its Rate. We have paid special attention to properties specific to Cultivars because, when selecting crops the farmers primarily consider basic features of a Cultivar not a Crop.

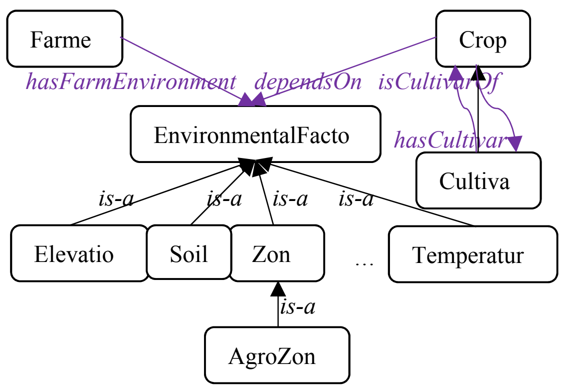

Figure 4: Relationships about Environment Concept.

Figure 4 represents how *EnvironmentalFactor* relates to Farmer and Crop; *hasFarmEnviornment* and *dependsOn* respectively. We have defined the environmental factors to be Zone, Elevation, Soil, Temperature, etc. which are subclasses of the *EnvironmentalFactor* (superclass) because in our application the union of these subclasses form the environmental factors which need to be specified for instances of crops as well as for farms. Since AgroZone is a subclass of Zone, then AgroZone is also subclass of *EnvironmentalFactor*. In here we have used the subclasses as a set of mutually-disjoint classes which covers *EnvironmentalFactor*. Every instance of *EnvironmentalFactor* is an instance of exactly one of the subclasses in the union.

Once the hierarchies and relationships have been identified, the next step is to define the informal competency questions (CQ) in a formal way using formal terminologies. Few examples are given below.

Note that, here we use unary predicates for representing concepts, binary predicates for properties and binary relationships. The interpretation of C(x) is that x is individual belongs to concept C.

CQ: *Which crops are suitable to grow in the 'LowCountryDryZone' agro-ecology region?*

Query 1:

$(\exists x)(Crop(x)) \wedge (AgroZone(LowCountryDryZone)) \wedge dependsOn(x, LowCountryDryZone);$

CQ: *What Brinjal's cultivars are good for 'Bacterial Wilt' disease?*

Query 2:

$(\exists x)\ (Cultivar(x)) \wedge Crop(Brinjal) \wedge hasCultivar(Brinjal,x) \wedge isCultivarOf(x,Brinjal) \wedge (\neg isAffectedBy(x,BacterialWilt)) \wedge (\neg affects(BacterialWilt,x));$

CQ: *What is the best Brinjal's cultivar which is suitable for 'DryZone' and high-resistance to the 'Bacterial Wilt' disease?*

Query 3:

$(\exists x)\ (Cultivar(x)) \wedge (Crop(Brinjal)) \wedge isCultivarOf(x,Brinjal) \wedge hasCultivar(Brinjal,x) \wedge hasDiseaseResistance(x,BacterialWilt) \wedge hasDiseaseResistanceRate(x,high) \wedge (Zone(z)) \wedge dependsOn(x, z) \wedge hasZoneType(z,DryZone);$

To perform above queries, definitions of the terms and constrains in their interpretation are specified using set of axioms in first-order logic. Here we have defined the axioms to express these definitions and constraints. The Table 8 shows some of the axioms used to represent above queries.

Table 8: Formal Axioms.

Express main climate zones in Sri Lanka based on annual rainfall (in mm): • $\forall x\ (Zone(x) \wedge (\exists y\ Integer(y) \wedge avgAnnualRainfall(x,y) \wedge (y<1750)) \leftrightarrow DryZone(x));$ • $\forall x\ (Zone(x) \wedge (\exists y\ Integer(y) \wedge avgAnnualRainfall(x,y) \wedge (1750 \leq y \leq 2500)) \leftrightarrow IntermediateZone(x));$ • $\forall x\ (Zone(x) \wedge (\exists y\ Integer(y) \wedge avgAnnualRainfall(x,y) \wedge (2500<y)) \leftrightarrow WetZone(x));$
Express main farmer types based on his/her cultivated land area: • $\forall x\ (Farmer(x) \wedge (\exists y\ Integer(y) \wedge sizeOfFarmLand(x,y) \wedge (y<35)) \leftrightarrow SmallFarmer(x) \vee GardenFarmer(x));$ • $\forall x (Farmer(x) \wedge (\exists y\ Integer(y) \wedge sizeOfFarmLand(x,y) \wedge (y>35) \wedge (\exists z\ Integer(z) \wedge maxWorkers(x,z) \wedge (z>12)) \leftrightarrow LargeFarmer(x) \vee CommercialFarmer(x));$
Express the planted land types according to elevation in meters: • $\forall x (Elevation(x) \wedge (\exists y\ Integer(y) \wedge maxElevation(x,y) \wedge (y<600) \leftrightarrow LowLand(x) \vee Pahatharata(x) \vee LowCountry(x));$ • $\forall x (Elevation(x) \wedge (\exists y\ Integer(y) \wedge maxElevation(x,y) \wedge (y<1200) \wedge (\exists z\ Integer(z) \wedge minElevation(x,z) \wedge (600<z) \leftrightarrow MidLand(x) \vee Medarata(x) \vee MidCountry(x));$ • $\forall x\ (Elevation(x) \wedge (\exists y\ Integer(y) \wedge minElevation(x,y) \wedge (y>1200) \leftrightarrow HighLand(x) \vee Udarata(x) \vee UpCountry(x));$

In this ontology, inference capability is to be represented by using inheritance and the first-order logic based axioms, i.e. it refers to the implicit knowledge derived from the ontology when reasoning procedures are applied to the ontology.

3 GENERALISING APPROACH

We have now generalised the specific approach that was first developed to create a farmer centric ontology for Social Life Networks. The Figure 5 shows the generalised approach. According to this approach, we first identify a set of questions that reflect various motivation scenarios. Next we create a model to represent user context. Then derive the competency questions incorporating user context with generic knowledge module. This step is a new contribution we have made in this paper. These competency questions are used to identify the concepts, relationships and axioms to develop the ontology.

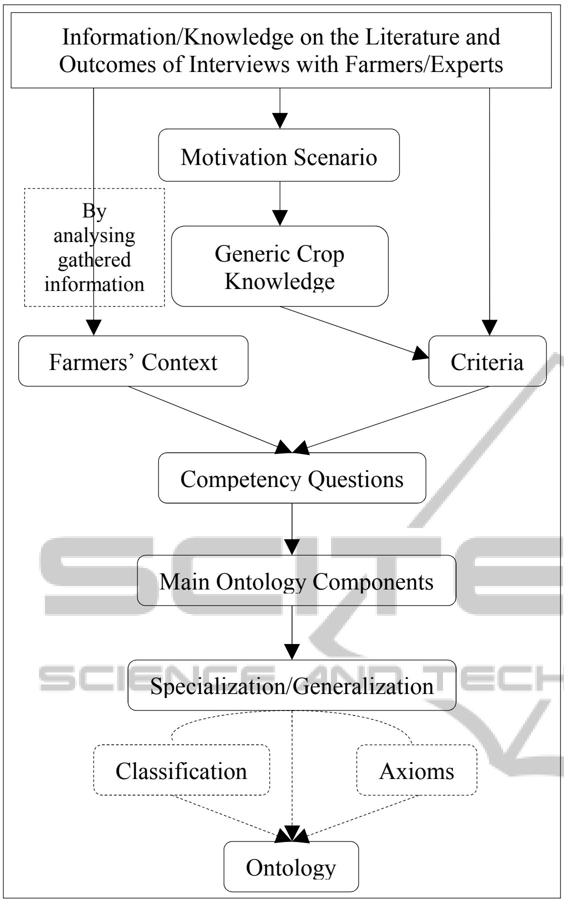

Figure 5: Our Ontology Design Framework.

Using this framework, we can extend the ontology for different scenario problems. For example, when answering scenario question like "*Which are the most suitable control methods to a particular disease?*" we need to take into account suitable criteria for selecting control methods and farmers' context. Then we can formulate the competency questions based on this systematic approach. These competency questions drive development of the ontology and can represent contextual information by satisfying user needs.

4 FIELD TESTING

A Mobile based application was developed to provide information to farmers using this ontology (De Silva et al., 2013). The ontology that we developed for crop selection phase was tested with a group of 32 farmers in Sri Lanka. These farmers were selected with the help of Agriculture extension officers from Matale District in Sri Lanka. In this district high percentages of people are involved in cultivating wide range of vegetables. The evaluation study comprised of a demonstration session where farmers were given a brief introduction to the research project and what is expected from them. First a training session was carried out to make farmers familiar with the touch screen technology. Next the crop selection prototype shown in Figure 6 was demonstrated while illustrating the key features incorporated into the application. Crop selection provides a list of crops that grow in the region based on farm location and farmer preferences.

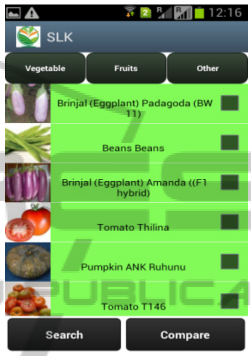

Figure 6: List of Crops related to Crop Selection.

After farmers used the application to select a crop that they want to grow they were asked the question "*Is all information for the crop selection stage provided*". They recorded the answer on a 1 to 5 Likert scale; strongly agree, agree, moderately agree, disagree, strongly disagree. The responses 7% strongly agree, 57% agree and 36% moderately agree. The farmers also suggested few areas where they would like to get more information.

5 CONCLUSIONS

In this paper we have presented a novel approach to derive the competency questions incorporating user context. These competency questions were used to identify the concepts, relationships and axioms to develop the ontology.

Overall objective of this research project is to design an ontology to cover all stages of farming lifecycle and to provide agricultural information and knowledge to framers in their own context. Designing this type of ontology is not a simple task, because it depends on many factors. In this paper we have briefly explained how we designed the ontology for the crop selection stage. For this we had to extend the ontology to incorporate user context. Based on the techniques that we discovered, we developed a generalised framework for ontology design that can be used to create knowledge repositories which are capable of providing information according to user context.

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