# Context Based Content Aggregation For Social Life Networks

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I would like to dedicate this thesis to my loving parents

Mr. K.C Mathai and Mrs. Annie Mathai

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# Abstract

Better decisions can be made in the profession of the users if they can filter out the relevant information from all the available information sources. The mass availability of the mobile devices has enabled the users to quickly access timely information from any location. The aim of this work is to identify a suitable way to provide timely information in context by capturing contextual information through the mobile device, to support the activities of the user. The context model tries to identify the context of the user by identifying the task being performed by the user. The system is aware of the information need and the information source for each task of the user and the relevant information is filtered out of the information source, by using the users context. The context model was designed and tested for the farming domain, to support the livelihood activities of the farmer, by extending the concepts of Social life networks. Social life networks aggregates information from various sensors on a mobile phone, other published data sources and micro blogs such as twitter to detect evolving situations and make that information available to the users in real time. This initial prototype was evaluated with a sample of farmers to check usefulness of provided information and usability of the application in order to support their day to day decision making process.

The sample group strongly endorsed the various aspects of the prototype application and provided valuable insights for improvement. The current application is a specific instance of the SLN project and we plan to create more application for SLN to test and refine the context models.

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# Chapter 1

# Introduction

Rapid growth of mobile phone usage has ensured that most of the people in the world have access to a mobile and this has triggered the development of large number of applications that provide different types of personalized services. Many researchers have identified that the inability of a person to filter out the relevant information from all the available information as the main reason that prevents the person from making better decisions (Babu et al. 2012; Lokanathan and Kapugama 2012; Parikh et al. 2007; Punchihewa and Wimalaratne 2010 ). The objective of this work is to identify a suitable way to provide timely information in context to support the activities of the user. Depending on the profession of the user, the objectives and hence the information required to carry out the activities varies from user to user. For example, a farmer might use it to find out what crop to grow and builder might use it to determine how to obtain raw materials for restructuring the floor of a house. Even in the same profession, the information required by the user varies depending upon the context in which the task is being performed. For example, the information required by a farmer to harvest a crop is different from the information needs of a farmer selling his harvest. These scenarios highlight the fact that the tasks performed by the users are different and the specific information required by the user for performing a task would be based on the domain in which it is being performed. Since the majority of the users have access to mobile, it would be a good idea to provide the required information to the user through a mobile application. To provide a personalized service, through the mobile device, the system needs to keep track of the users context and the focus of this thesis is to provide a framework that can support the information need of a user based on the profession by identifying the task context. It tries to extend the concept of Social Life Networks (SLN) proposed by Jain and Sonnen (2011 ) to aggregate information from various sensors on a mobile phone, other published data sources and micro blogs such as twitter to detect evolving situations and make that information available to the users in real time. SLN extend the information sharing concept in Social Networks (Giles 2010 ) and aims to provide timely information in context.

An international collaborative research project was launched to develop Social Life Network applications that could provide necessary information to support livelihood activities of people living in the developing world. The first project of this research group was a mobile application for farmers. The application that has been developed provides dynamic information such as market prices and current level of production derived in real time. The application also provide static information such as what crops will grow in a specific region, information about required fertilizer and pesticides etc (De Silva et al. 2012 ). Further this information will be delivered based on the users context (Walisadeera et al. 2013*a* ) as well as in a way to empower the user to act on this information (Ginige;

et al. 2012; Ginige and Richards 2012 ).In this work my focus is to create and use different context models to meet the information needs of farmer to support their livelihood activities. The context module would be the core processing unit of SLN that would require interactions with the other modules of SLN to determine the best suitable way of providing the relevant information for farmers.

In Sri Lanka over production of vegetables is a regular problem due to many farmers growing the same crop without being aware of what others are cultivating (Hettiarachchi 2011, 2012 ). To avoid this, farmers need to know the current production levels at the time that they are deciding what crop to grow. This will enable them to decide whether there is going to be a surplus at the time they take the harvest to the market. The context model presented in this thesis together with work done by other researchers were used to develop a mobile based information system for farmers to address the over production problem. The solution that is proposed can be part of the solution to the agrarian crisis and many other similar problems in different professions. The context model can also provide the information required to meet the goals of different profession by providing the information in the context of the task being performed.

## 1.1 Research Objectives

In order to physically realize this vision, one of the area in which in-depth research is required is the process of providing information in context. Context awareness refers to the idea that system can both sense, and react based on their environment. Providing information in context helps the user to obtain specific information rather than generic information. Providing information in context leads to effective knowledge which has the potential to increase the productivity and income since this information is more relevant to their task and better reflects the individual needs of the user. The objective of my work is to determine precise requirements in implementing context based information service to support the activities and tasks of the user.

## 1.2 Research Questions

The core goal of this thesis is to demonstrate that it is possible to effectively provide relevant information to users from a wide range of information source by identifying the context of the user based on the task performed by the user. In more detail, we investigate and try to solve the following research questions: *How to identify the factors specific to a domain and provide information in context for the user?*
To find and answer to the above question I formulated the following three investigative questions.

1. What is an effective model to represent user context in a domain?
2. How to identify and capture user context from sensory and user action?
3. How to query the different information sources and aggregate that information based on context?

## 1.3 Contribution

The results of this thesis are contributions to the study and improvement of context based information retrieval, with the main contribution being the design and evaluation of context models, based on users task, which tackles the problem of efficiently delivering relevant information to the user performing the task to make effective decisions. We have developed a generic context model that can be used to provide relevant information to users. This has been used to develop a farming application that can provide support to the decisions made by the farmers for their livelihood.

## 1.4 Thesis Outline

The remainder of this thesis is structured as follows:

Chapter 2 introduces notations and core concepts, such as the Context, Context Classifications and provides justification for using context based content aggregation in farming domain.

Chapter 3 introduces the design methodology used in the development of context model and the farming application.

Chapter 4 presents core concepts associated with the task based context model and provides a generic model for capturing physical context.

Chapter 5 details our investigation scenario which led to the development of farming application and describes the analysis of the farming domain to design the application based on the context model described in chapter 4.

Chapter 6 contains the architecture for SLN, a detailed explanation of the physical implementation of the context based content aggregation module for the farming application, the evaluation of the effectiveness of the farming application.

Chapter 7 concludes the work, provides a detailed reflection upon the work in this thesis and evaluates the work based on the research questions.

# Chapter 2

# Literature Review

The objective of this section is to review the current ongoing research in context modelling and context based information extraction. In order to get a deeper insight into research challenges and to investigate possible solutions a specific real world problem in farming domain is chosen and advantages of developing a context based application is reviewed. This section also reviews the way to develop meta models that can be configured to work with different domains.

## 2.1 Need for Context

In order to design applications for dynamic environments, it is necessary to understand the classifications of context and the concept of context- awareness. Due to the richness of the language used and the common understanding humans have about how the world works, human communications are quite successful and seem to be very easy (Dey 2001 ). Human communication is more successful when there is an implicit understanding of the everyday situations of others who take part in the communication.For example, in a conversation between two friends, the question *How was the game?* might not require any further elaboration. This question is incomplete, as it does not explicitly describe the game. Still, the respondent can understand the question. This is possible if the humans involved in the communication share a lot of common knowledge, and know the everyday situations of each others lives. Moreover, the type of the answer expected is not mentioned in the question. However, it is understood that the answer is not only about who won the game, but also should include descriptions of the game, such as the scores.

For an automated system to have the ability of bringing this contextual information in the interaction between the human and the computer is challenging. By improving the computers access to the context, the richness of communication in human computer interaction can be increased, giving more useful computational services (Seher et al. 2007 ). Emerging ubiquitous or pervasive computing technologies offer *anytime, anywhere, anyone* computing by decoupling users from devices (Dey 2001; Hill et al. 2004; Kwon, Choi and Park 2005; Kwon, Yoo and Suh 2005; Schilit et al. 1994 )and to provide adequate service for the users, applications and services should be aware of their contexts and automatically adapt to their changing contexts-known as context-awareness (Bolchini et al. 2007; Dey 2001; Zhu et al. 2005 ).

## 2.2 The Context

Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including location, time, activities, and the preferences of each entity (Dey 2001 ). Dey (2001 ) defines context as any information characterising a situation related to the interaction between users, applications and the surrounding environment. Growing research activity within the realm of ubiquitous computing deals with the challenges of context awareness (Baldauf et al. 2007 ). Context-awareness means that one is able to use context information. A system is context-aware if it can extract, interpret and use context information and adapt its functionality to the current context of use (Byun and Cheverst 2004 ). Dey (2001 ) provide an operational definition of context and discusses the different ways that context can be used by context-aware applications. This work provides concepts and practical support for software design and construction of context-aware applications with the intention of providing additional support for application developers.

Schmidt (2013 ) states that understanding the context of use is essential for creating applications that are easy to use. With Context-Aware Computing the system can decide what the current context of use is and provide a user interface specifically optimized for this context, thus eliminating the unnecessary need for user cooperation. To illustrate this concept, Schmidt (2013 ) describes an example where the user interface for a wristwatch is designed. The watch needs to adapt to different situations such as when the user is running to catch a bus or when attending a boring lecture.


Figure 2.1: Design sketches that illustrate time visualisations in different contexts.(a) For users running to catch a bus, making it easy to see the minutes in large fonts. (b): For boring lectures and meetings, showing a countdown to the end, with some information to engage the user. (c) Visualisation giving only a very coarse idea of the time, similar to information you get from the sun, to use for example when hanging out with friends when time does not matter (Schmidt 2013 )

The context-aware computing approach enables one to create a context-aware watch, where all situation-optimised designs are combined in a single design. The watch is designed so that it can recognise each of the situations, and then reconfigure itself based on the recognised context. Figure 2.1 shows a design sketch for a context-aware watch.

### 2.2.1 Classification of Context

Schilit and Theimer (1994 ) refer to context as comprising location, identities of neighbouring users and objects and changes to those objects. Brown et al. (1997 ) define context as location, identities of neighbouring users, time, and environment characteristics such as season and temperature. Ryan et al. (1998 ) define context as the users location, environment, identity, and the time. Dey et al. (1998 ) states that context is the users emotional state, focus of attention, location and orientation, date and time, objects and people in the users environment. All of these definitions characterise context by examples, and as such their application is difficult.

Schilit et al. (1994 ) argue that the only important aspects of context are user location, the users neighbour, and resources near the user. Furthermore, they define context to be subject to the constantly changing execution environment.

Dey et al. (1998 ) defined context as *Any information that can be used to characterise the situation of entities (i.e. whether a person, place or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves.* Using Dey et al. (1998 ) definition, Chihani et al. (2011 ) observed that context information may be classified according to the described entity.

The context of users may be a combination of various entities such as their identity, activity, location and mood; their social context may be the nature of their relationship with other persons (e.g. family member, colleague, friend); and their physical context might include (for instance) the lighting level of the location where they are. The context of a network may be its quality of service parameters, like round-trip time, and the context of a device may be its capabilities, display features or battery level (Chihani et al. 2011 ). Dey (2001 ) introduced a simple classification of context information based on the entities for which context is assessed, with four essential characteristics of context information: identity, location, status (or activity) and time. Identity refers to the ability to assign a unique identifier to an entity. Location is expanded to include orientation and elevation, as well as all information that can be used to deduce spatial relationships between entities, such as co-location, proximity, or containment. Status (or activity) identifies intrinsic characteristics of the entity that can be sensed. Time helps characterise a situation, enabling us to leverage the richness and value of historical information.

### 2.2.2 Context Information Acquisition

The goal of context information acquisition should be to determine what a user is trying to accomplish. Because the users objective is difficult to determine directly, context cues are used to help infer this information and inform an application on how best to support the user.

Context-aware applications are often distributed because they acquire context information from a number of different sources (Dey et al. 1998 ). The raw data of low-level context are usually gathered from different physical sensors. Data type, formats and abstraction level from different physical sensors are different. Devices and physical sensors of context-aware systems use various scale and unit, and low-level context has different elements. Context-aware systems store data, information and knowledge that have different relationship, format and abstraction level in the context base. Furthermore, context-aware systems collect context history storing sensor data over time to offer proactive service. Context history stores huge amount of data on location, temperature, lighting level, task, utilized devices, state of devices, selected services and so on. To quickly provide suitable service to users, context-aware systems should manage variety, diversity and numerous amount of context. Therefore, a methodology and real implication for treating variety, diversity and numerous mount of context are needed.

### 2.2.3 Situation Analysis

Jain and Sonnen (2011 ) proposed that there are a few basic components for realizing the vision of social life networks (SLN); designed not only to connect people with other people, but to connect people with other people and essential life resources. These basic components are shown in figure 2.2. Data coming from multiple users and heterogeneous devices needs to be wrapped into a common format and made accessible to the system. Logically the data needs to be translated from localized sensor/human input to higher-level situational abstractions. There is also an encompassing issue of user engagement. Both intrinsic and extrinsic factors matter, but enhanced feedback and user motivation are key aspects of it. The biggest catalyst for the adoption of the traditional Web was the presence of search engines which routed users to their desired resources (static web pages).

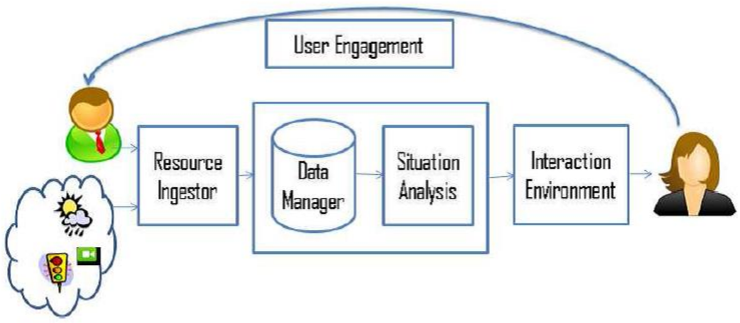



Figure 2.2: Essential components for realising social life networks (Jain and Sonnen 2011 )

A situation analysis performs a similar role in the dynamic social life networks i.e. routing the users to the appropriate resources based on situation detected (Jain and Sonnen 2011 ). To carry out the situation analysis, it is vital to identify the context and using the contextual information will result in a more personalized set of results for the user.

## 2.3 Context-specific Information for Agriculture

Babu et al. (2012 ) discuss clearly the importance of contextualized information and knowledge for the farmers in India. They further explain how effective this knowledge can improve their productivity and income since this information is more relevant to their farm enterprises and better reflects needs of the farmers. They therefore recommend that the existence of context-specific and relevant information should be considered when developing approaches for farmers. Diekmann et al. (2009 ) explains that information must be relevant and meaningful to farmers, in addition to being packaged and delivered in a way preferred by them. Context-specific information could have a greater impact on the adoption of technologies and increase farm productivity for marginal and small agricultural landholders (Samaddar 2006 ) cited in (Babu et al. 2012 ). However, making information context-specific is more resource intensive. It requires information at the farm level, which could vary spatially and temporally, and with different degrees of specificity (Babu et al. 2012 ). Despite the additional cost and time associated with generating localized content, this content could be more relevant and useful in meeting farmers information needs (Cecchini and Scott 2003 ) cited in (Babu et al. 2012 ).

## 2.4 Meta Model

To find an effective way to develop context models for mobile-based applications rapidly and in a cost-effective manner that can evolve with changing domain and information requirements , we need to review similar method that have been adopted in the development of rapidly evolving web-based application.

Ginige (2008 ) purposes that instead of developing specific applications, to develop a meta-application or framework to capture the knowledge of business users and from this to generate the business applications, so when the requirements change the changes can be captured and used to recreate the applications. The approach was to identify the different aspects of various business applications, create a meta-model to capture these aspects of a business application, develop necessary software modules to create the business applications using the meta-model instance data and to develop a framework to provide functionality common to all applications.

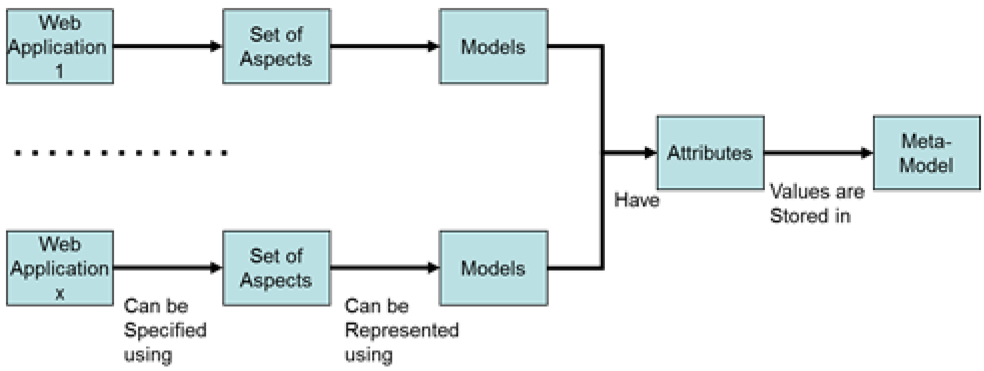



Figure 2.3: Meta Model (Ginige 2008 )

Ginige (2008 ) purposes that the relationship between a web application and the meta-model is as shown in Figure 2.3.

# Chapter 3

# Research Process

This chapter discusses, the research techniques and procedures employed to design an effective context model to provide information in context to support the tasks being performed by the user. This research project employs a research approach known as Design Science to address the research problem, it is often presented as a relatively new approach within the Information Systems discipline (Hevner et al. 2004 ).

Firstly, awareness of the problem came about through discussions with the research members of Social Life networks (SLN) and the academic supervisor. Through discussions it was identified that the major requirement for next generation of mobile applications is to find the relevant and meaningful information for the user at the correct time (Ginige and Ginige 2011 ). This requires intelligent ways to aggregate information from different source to identify events that are taking place at personal, local, regional and global level. It has also identified that these systems should also be capable of receiving information from a large number of users; aggregating this information in near real-time and making this aggregated information available to users (Ginige and Ginige 2011 ). I identified that, while there are a number of theories and frameworks around providing relevant information, none specifically addressed the question of providing relevant information in context. The research group was keen on determining the best suitable way of providing the relevant information as it was the core processing unit of SLN that would require interactions with the other modules of SLN.

In order to tackle this research question I needed to come up with solutions to satisfy the problem requirements. The solution could be achieved through insights that ideas (theories, constructs and measures) from the disciplines of information technology could provide that is beneficial in tackling this problem. These ideas are not readily transferable: it requires an understanding of the literature, information system practice process, formalisation into an artefact and evaluation against some criteria. The design and evaluation methods had to be carried out to make sure that the suggestion could work and form the solution to the problem. I had to choose a research methodology which closely resembled the objectives to be attained through this research work. As a result I opted for design science research methodology.

## 3.1 Design Science Research Methodology

Maylor and Blackmon (2005 ) defines *Research* as *A systematic process that includes defining, doing, and describing an investigation in to a research problem.* Moreover it is a process of information gathering, investigation of the unknown, to solve a problem (Maylor and Blackmon 2005 ). Research process is the general plan regarding how research questions will be answered by the researcher

(Saunders et al. 2011 ). According to Thomas et al. (2011 ) an investigation in to research techniques and procedures or methods that adds value to a research in many folds. In particularly, they identify four distinctive positive outcomes as:

1. makes the researcher aware of the wide range of research methods available to collect and analyse data;
2. makes the researcher aware of certain *dos* and *don'ts* in applying a certain research method;
3. provide insights in to overall research process;
4. helps to identify what constitute a good or poor research.

Vaishnavi and Kuechler Jr (2007 ) defines a research paradigm as: *the set of activities a research community considers appropriate to the production of understanding (knowledge) in its research methods or techniques.* Research paradigms in Information System research are two fold. It can relate to behavioural science or design science (Hevner et al. 2004 ). Behavioural science address research through developing and verifying theories attempting to explain or predict phenomena related to the identified business need. Design science on the other hand tries to create new and innovative artifacts to extend the boundaries of human and organizational capabilities. Behavioural science seeks to find the truth and often researcher starts this journey with a hypothesis. The goal of design science research is utility. Hevner et al. (2004 ) argue that truth and utility are inseparable. Chatterjee (2010 ) defines Design science paradigm as *a research paradigm in which a designer answers questions relevant to human problems via the creation of innovative artifacts, thereby contributing new knowledge to the body of* *scientific evidence. The designed artifacts are both useful and fundamental in understanding that problem. It is fundamentally a problem solving paradigm.*

In order to tackle the context based content aggregation problem, it is important to understand what form a suitable response might take and how it might be used in practice. The over-riding consideration here is to utility rather than truth. That is, the research is primarily concerned with producing a framework that is useful to solve the problem as opposed to discovering an underlying truth about the world. The knowledge acquired is hence of an applied nature. In this case, there must be a structured approach to building and evaluating the framework to ensure it has rigour and relevance. As Hevner et al. (2004 ) argue, IS research needs to be rigorous to provide an *addition to the knowledge base*, and relevance allows for *application in the appropriate environment*. The design science research methodology allows me to do this for the identified problem.

## 3.2 Employing Design Science In Research

The research activities of design science within the IS discipline are described via a conceptual framework for understanding information systems research and a clear set of guidelines or principles are prescribed for conducting and evaluating good design science research (Hevner et al. 2004 ). The specific model of Design Science selected for use here is that presented by Hevner et al. (2004 ). This model was selected as it is well-developed, recent and published in the top journal for Information Systems. This suggests it is of high quality, accepted by researchers in this field and likely to be a reference source for a number of future projects. It also presents a number of criteria and guidelines for critically appraising Design

Science research, which govern the research project.

This model makes explicit the two modes (develop/build and justify/evaluate) and links these to business needs (relevance) and applicable knowledge (rigour). This sits squarely with the applied nature of this project. The environment defines the problem space (Simon 1996 ) in which reside the phenomena of interest. The environment creates the business needs which ensure the research meets the goal of relevance. Hevner et al. (2004 ) argue that the business need is *assessed within the context of organisational strategies, structures, culture and existing business processes.*

The 2004 MISQ paper presents design science as a research paradigm to be employed in IS research projects. As such, the discussion does not propose a detailed process for performing design science research. However, a key insight can be gained by identifying and understanding the existence of three design science research cycles in any design research project as shown in Figure 3.1 (Hevner 2007 ).

The relevance cycle identifies the design requirements of the research question, the environment in which the artefact can be introduced, how the artefact is to be used in the environment, how it is to be field tested and what metrics are used to demonstrate the successful use of the artefact. The Rigor Cycle ensures that the design is based on scientific theories and methods to produce a new knowledge base of artefacts useful to the research community. The Design Cycle iterates between the core activities of building and evaluations of the design artefacts and processes of the research. It identifies how the artefact is represented, what design process or heuristics are used to build the artefact as well as what evaluations are performed during the design. It also identifies design improvements based on feedback obtained from the environment during design cycles.

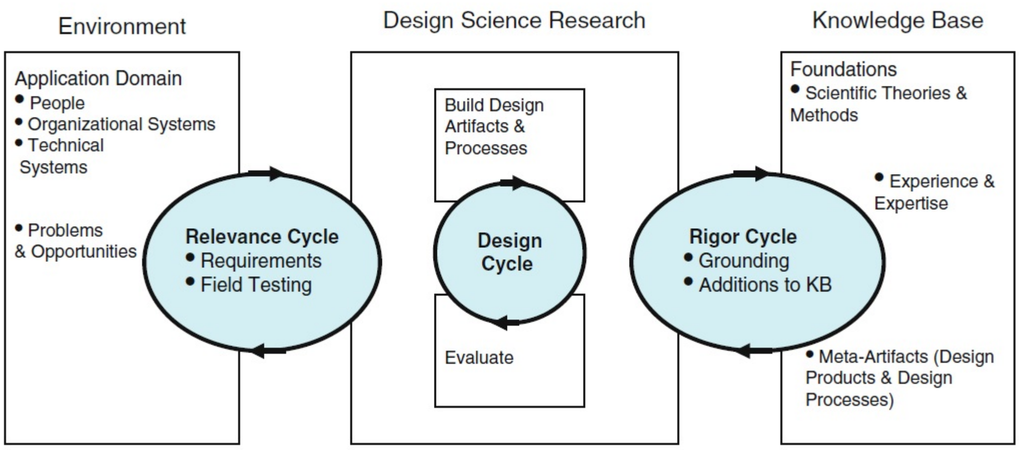



Figure 3.1: Design science research cycles (Hevner 2007 )

Starting from the activity *identify design requirements* in Relevance cycle the researchers can move among different activities in different cycles to create the artefact. At the end all specified activates had to be completed. The order is not prescribed.

In this work, the business needs are driven by the objective of providing the information in context. The specific domain chosen in order to illustrate the effectiveness of the work is the farming domain and the objective is to provide effective access to information for farmers to help them with the problem of agrarian crisis. Lack of information at an early stage about the production level of the crops prevents the farmer from making an informed decision. Based on research carried out by Lokanathan and Kapugama (2012 ) and De Silva et al. (2012 ), the picture that has emerged is that farmers need specific information rather than generic information.

In the relevance cycle, the objective is to identify the different activities and tasks that are being performed in the farming domain. The research carried out by Lokanathan and Kapugama (2012 ) and De Silva et al. (2012 ) gives us a deep insight into the day to day activities of the farmer. The work done by (De Silva et al. 2012; Walisadeera et al. 2013*a* ) has been used as the requirement that drives our work and forms part of the relevance cycle. This knowledge would be then used to identify the requirements needed to create a generic model which would be able to handle the decision making process for any activity belonging to any profession. The first prototype developed was evaluated with farmers to determine the shor comings in the design of the artifact. This is also part of relevance cycle. The section 5.2 and the section 6.6 describes the relevance cycle of this work.

The literature review is the first phase of the Rigor Cycle for our work. The Rigor Cycle ensures that the design is based on scientific theories and methods to produce a new knowledge base of artefacts. Once the validity of these artefacts are established the researchers contribute this new knowledge back in to scientific knowledge base mostly as published papers. This is the second stage of the Rigor Cycle. The chapter 2 and chapter 4 describes the rigour cycle of this work.

The high-level requirements that the context based farming application should satisfy is that information needs to be provided in context of the task being performed by the farmer. Framers need relevant information at different stages of the farming lifecycle. Most of the information farmers need is available from varying sources. But one has to spend fair amount of time searching these sources to find the information relevant to a particular information need. Thus the proposed MBIS need to find the information related to farmers current context from multiple sources, aggregate and provide the information to farmers. To motivate farmers to use the system which is essential for long term sustainability there is the need to provide a mechanism to empower the farmers. As the information is provided through mobile phones, appropriate web services based interaction environments needs to be provided to cater to the needs of the interfaces that farmers can use to easily obtain the information that they need at the time. These identified needs provided input for the design Cycle in the overall research approach.

In the Design Science Research approach, it is in the Design Cycle the artefacts get created based on the requirements identified in the Relevance Cycle. This cycle broadly consists of 2 phases, designing and evaluating for functional correctness (i.e. whether the artefact is correctly constructed). The evaluation of whether the artefact meets the identified domain/user needs happen in the relevance cycle (i.e. whether the correct artefact has been developed). The researchers have to find an appropriate design methodology to carry out the design phase of this cycle.

The design challenge was to find a way to provide information in context. For this we need to create a model to represent farmer context when they are searching for information. Using sensory information that we can obtain from mobile phones we need to derive the values for various model attributes. Using this farmer context at the time we need to query different data sources to find the information farmers need, aggregate these and send to the farmer.

The design cycle needs to iterate through a number of times to become more robust. For this work only one version of prototyping was achieved. But for the internal design cycles, it went through a number of iterations as explained in section 6.4.

# Chapter 4

# Task Oriented Context Model for Mobile Users

This chapter identifies the different subset of knowledge required from the domain for performing an activity and the knowledge required to develop an application in a domain. The context models that can be used to obtain relevant information from different information sources have been presented in this chapter. This chapter also proposes a generic model to capture the physical characteristics of an entity, where an entity is a person, place, or object that is considered relevant to the interaction between a user and an application.

Activity is a set of tasks performed by a user. A sequence of activity is performed within any domain to accomplish a goal. For example in farming domain, a farmer needs to perform a number of activity; from selecting the crop, preparing the land to selling his produce; to achieve his goal. In order to complete each of these activities, the user has to perform a set of tasks for each activity. For example, for preparing the land, the farmer needs to carry out ploughing, destruction of weeds, incorporation of organic material, incorporation of fertilizers and lime, and development of the proper seed bed.

The tasks and activities are driven by the final goal or objectives of the user and for each of these tasks to be completed the appropriate information needs to be provided. In task oriented context, the contextual information is used to determine the context of the user performing a task; the context can be then used to provide the required information to achieve the goals of the task to be performed. Thus, the task to be performed is identified and the task oriented contextual information is then used to filter out the relevant information.

## 4.1 Modelling Context

Brézillon (2003) gave an interesting description of the context by delimiting it in three intertwined spaces: external knowledge, contextual knowledge and proceduralized context, where pieces of knowledge can enter a new space as the work changes as shown in Figure 4.1.

Proceduralized context, the context which is shared by those involved in the problem and is directly but tacitly used for the problem solving; Contextual knowledge, the context that is not explicitly used but influences the problem solving and External knowledge, the context that has nothing to do with the current decision making but is known by many of those involved.

Brézillon (2003) defines context as the sum of all the knowledge possessed by the operators on the whole activity. Brézillon (2003) postulates that context is task-oriented and at a given step of a decision making process, the user is responsible for separating the part of the context that is relevant, and the part which is not relevant.

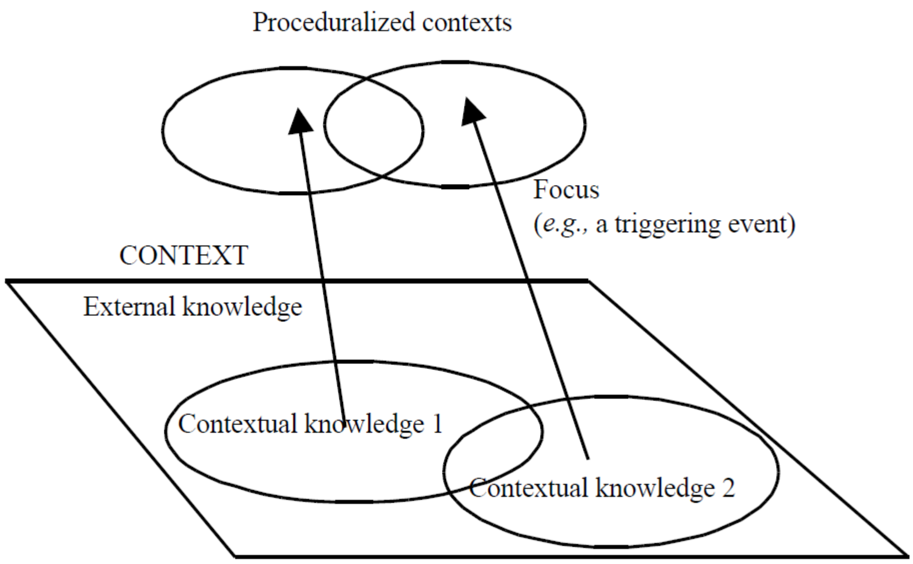



Figure 4.1: Different type of Context (Brézillon 2003 )

## 4.2 Types of Knowledge and Context Models

To provide relevant information to a user we need to determine the context of the user. The context models that helps to identify the context of the user has been proposed in this section and the different knowledge which shapes the context is identified.

### 4.2.1 External or Domain Knowledge

External or domain knowledge is the sum total knowledge about the domain, it is the collective knowledge, and it includes both the tacit and explicit knowledge. Most of the knowledge of a domain is captured in the written form.The knowledge about a domain can be organized in many ways. Different type of organization can be done. The organization would be influenced by the higher level of concepts in the domain. For example, knowledge can be structured using ontology, explicit formal specifications of the terms in the domain and relations among them (Gruber et al. 1993 ). The ontology can be created by capturing the explicit information from written sources such as books, journals and research papers and the tacit knowledge can be captured by interacting with experts in the field. Thus, ontology is a process to organize the external knowledge, based on the important concepts of the domain. Better organization of knowledge in domain allows more flexibility in accessing information. Information can be obtained at macro level, or as a large list or as small bit of information depending on the level of organization of the information in the domain knowledge source.

In farming domain, the external knowledge contains information on growing all types of crops, for example, the agriculture department have a leaflet that explains the process of growing a crop based on time, environmental and climatic condition, but a farmer would require only a subset of that information, ie information on growing a particular type of crop. So there needs to be a match between information need of the user and information organization. But the problem is that, in the existing systems, information are stored and organized to match a specific need, but the requirement is that information is needed in changing context and thus having information organized to meet a specific need is ineffective. Depending on specific requirement of the task being performed, we need to capture the specific subset of information from the domain knowledge. It is important to have the appropriate structuring for the domain knowledge to provide the task specific information.

### 4.2.2 Task Knowledge

The structured knowledge does not have any relation to the task being performed, but deals with how the information is partitioned in a domain. The task knowledge contains all the activities that the user needs to perform to accomplish his goals. For each activity a number of tasks need to be accomplished. To perform a specific task, we take a subset of knowledge from the domain knowledge which matches the information requirement of the task being performed. The collection of all the activities along with the information requirement of each task of the activity is known as the task knowledge.

Task knowledge can be captured by looking at the decision made by users, the information required to make this decision and the tasks that they perform (Johnson et al. 1988 ) . For example, in farming domain, if the farmer wants to make a decision on crop selection, his selection would be influenced by information applicable to crop selection such as soil, weather patterns, climatic condition, fertilizers etc. For an activity crop selection, the task knowledge is the subset of the information from the domain knowledge that is required for carrying out all the tasks for crop selection.

### 4.2.3 Procedural Knowledge

Now, from all the information required by the task knowledge, we require only a smaller subset of information to fulfil an individual task, and the knowledge required to filter out this information is known as the procedural knowledge. The procedural knowledge is responsible for identifying the source of information and the higher level concepts used to structure the information in the information source. The procedural knowledge includes the query that needs to be generated, the query parameters and the mapping required to convert the parameters to higher level concepts of the information source. This knowledge is used to filter out the required information from the information source.

For example, for carrying out crop selection we would require information which is specific to the area in which the activity is taking place. Information specific to the user is provided by filtering out the required information to suggest the crop that would grow in his farm land. The domain knowledge would give us a list of crops that would grow in a specific land condition, and the users location should now be matched with the land condition specified by the domain knowledge to obtain the list of crop that would be suitable for users location. If the users location is represented in a different spatial format than the domain knowledge then there should be a mapping between the users location and the spatial format specified by the domain knowledge. This mapping is also part of the procedural knowledge.

Let us consider another example, in farming domain; the domain knowledge has knowledge on fungus, which contains information such as a description of fungus, different type of fungi, methods to prevent fungal infection and methods to add fungal specific pesticides. The domain knowledge also has information that can be used to deal with different types of fungal infection. By identifying the specific fungal infection, the information need of the task is reduced as we only need to identify the pesticide required to prevent the specific fungal infection, thus only a subset of information from the domain knowledge is used, which forms the procedural knowledge.

The figure 4.2 captures the concept of the different knowledge in a domain.

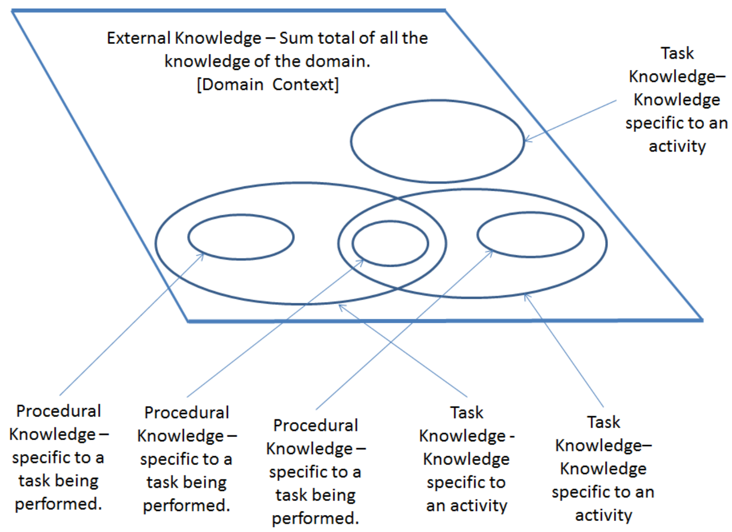



Figure 4.2: Different types of Knowledge

### 4.2.4 Application Domain Knowledge

The application domain knowledge is the specific information that is relevant to the domain in which the application is being developed, it is the knowledge required to develop an application in a domain. This knowledge is captured in the form of a software requirements specifications, which is a complete description of the behaviour of the application and the interactions the user will have with the application. The application domain knowledge is independent of the task knowledge, but the application domain knowledge determines the attributes and relationships that need to be captured which is used by the procedural knowledge as query parameters to filter out information from different information source.

For example, in the farming domain, the application domain is independent of the farming practice, but relies on the way farming is being carried out. The location in which the task is being performed is one of the key factors that influence the filtering of the relevant information from the information source and the farming domain is a specific domain in which the user can have multiple locations, in the form of different farms, associated with them and the application domain knowledge helps us to capture this specific knowledge that is only applicable to the farming application.

### 4.2.5 Context Models

The physical context attributes are the raw environmental parameters which are captured in real time using sensors or pre stored in the system. The physical context is designed based on the analysis obtained from the application domain knowledge. Thus, the application domain knowledge specifies the structure and attributes of physical context. Each user of the application will have different physical values according to their settings. The task context is the current activity that is being performed by the user. The task context would be one of the task that has been defined as part of the task knowledge. Every task would have its own domain based logical interpretation of the stored physical data. The system needs to map the physical context to higher level concepts of the domain knowledge to get relevant information based on task being performed.

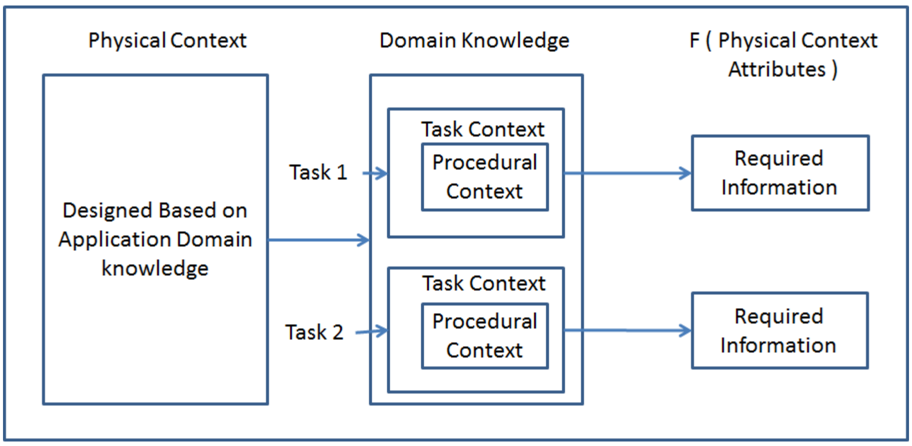


Figure 4.3: Context model to retrieve required information

The procedural context is generated by combining the task context with the physical context. The procedural knowledge is used to identify the attributes of the physical context that needs to be mapped into higher level concepts used in the domain knowledge. After the mapping, the higher level concepts is used as the parameters of the query to filter out relevant information from the information source. Thus, the different contextual knowledge is used to match the information organized in the domain context to the users context to filter out relevant information. An appropriate organization of knowledge in the domain is required to provide information to users based on task. The figure 4.3 captures the different context models that are used to retrieve the relevant data from the information source.

Consider an e-commerce scenario, where the objective of the application is to buy or sell products. One of the activities that can be performed on the application is to browse different product and identify the cheapest available price for the product. Now based on the location of the user, the application is responsible for identify the currency of the user and then perform the necessary conversion so as to identify the cheapest product by searching for the same product which have prices specified in different currencies. The task context for this e-commerce scenario, is the task of buying cheapest priced specific product, which limits the information need as the application needs to focus only on the price information that corresponds to a specific product. One of the attribute of the physical context for this application would be location, which contains the geo-coordinates of the location from which the application is accessed. The procedural context combines the task context and the physical context to determine the cheapest price.

The procedural context uses the physical context attribute location to identify the currency of the user and it is then used as the base currency. The currency is the higher level concept in which the information is organized and the physical attribute needs to be mapped into this higher level concept for easy filtering of the relevant information. The procedural information provides the information source and the information source is filtered to obtain relevant information by filtering the price of the product in the information source based on the base currency. Thus, the use of context model helps in providing relevant information which can lead to better decisions.

## 4.3 Designing the Generic Model for Physical Context

In addition to identifying the context models, we also need to model the physical context, as we have to use the different physical attributes to identify the context in which the task is being performed. A generic model for physical context is proposed in this section by analysing the reference architecture for Context aware applications based on the work of Bardram and Hansen (2010 ) and Seher et al. (2007 ).

### 4.3.1 Reference Architecture for Context Aware Application

Bardram and Hansen (2010 ) shows sample reference architecture for context-aware computing systems where the goal was to design a general-purpose architecture that could be applied in the design and development of different end-user applications running on different types of devices. This work showed that context-based workplace awareness can be divided into four dimensions:

- Social - an awareness of the social context of the work, i.e. an awareness of the people at work and what they are doing right now.
- Temporal - an awareness of the progress of activities over time: past, present, and future.
- Spatial - an awareness of particular physical locations (both co-located and remote) and their context.
- Activity - an awareness of particular activities and the context in which it is being performed.

Seher et al. (2007 ) proposes that in addition to the temporal and spatial context attributes, the context of the user who performs the task also plays an important role in identifying the context in which the information is required. Based on the work of Bardram and Hansen (2010 ) and Seher et al. (2007 ) a generic model for physical context is proposed.

### 4.3.2 Generic Model for Physical Context

Physical context can be modelled using user profile, spatial and temporal as major sub categories, to capture the part of the context associated with the user. Each sub category will consist of further sub categories and attributes.

**Profile Modelling:** This consists of the user context, such as the users profile and preferences. Some of these are general or domain-independent to a user.

Examples include the user's personal characteristics such as profession, age and gender. Some other user preferences are specific to the domain or application in consideration. These could be the user's level of knowledge of particular topics, and the users level of interest in particular topics. Starting from the identity of a user, it is possible to obtain individual context information. This can be achieved by having a registration system which manages the basic user profile.

**Spatial Information:** This context type describes aspects relating to the spatial extent of the user context. It can contain attributes like location, direction and speed. One of the most common contexts used is the location of the user. Location-awareness is the most important part of context-awareness for mobile computing systems. The spatial region of interest defines the physical boundaries and may be of any shape. Spatial context is represented as regions, spatial relationships and geometric coordinates.

In a regional representation, a boundary is specified as regions, such as Australia, Sydney or Parramatta. These representations can be hierarchically organized. Spatial relationships can be direction relationships (above, below, or north of, southwest of), topological relationships (near, far, around, within, adjacent, inside), and metric relationships (distance).The geometric coordinates specify points or areas in a metric space that represent the latitude, longitude and elevation above sea level.

A users location can be sensed using Active Badges, radar, video cameras or GPS (Global Positioning System) units. GPS sensors have become available in very small package sizes, enabling their integration in mobile devices. The level of precision required by the GPS module will depend on the information requirement of the application. For some applications there could be instances where multiple geo-coordinates may be made associated with an individual user profile.

**Temporal Information:** This context type describes aspects relating to time. Time is a fundamental variable, since the context is dynamic and changes with time. A temporal context can be represented as time instants or absolute time references, time intervals, periodic descriptors, and temporal relationship.

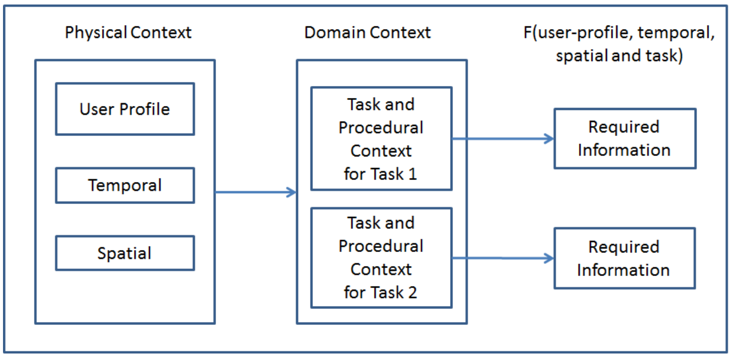



Figure 4.4: Generic model of physical context to retrieve the relevant data from the information source

A time instant or absolute time reference is an instant of time that is an absolute moment of time. It can be different in time units such as 9.00 a.m. and 11/10/2005. A time interval is based on calendar units such as year, today, morning. It is the time interval between two absolute time references. The figure 4.4 captures the different context models along with the generic model for users physical context that are used to retrieve the relevant data from the information source.

# Chapter 5

# Application Scenario

One of the remarkable achievements in recent times in the field of Information technology has been the concept of Web 2.0. The uptake of web 2.0 has been driven by wikis, blogs, social networking and bookmarking sites, with millions of users visiting sites like Facebook for social networking; Wordpress for blogging; Twitter for micro-blogging; Flickr and YouTube for photo and video sharing, Digg for social news reading; and Delicious for social bookmarking. Butler (2012 ) defines web 2.0 as a wide array of web-based applications which allow users to collaboratively build content and communicate with others across the world using the web as a platform for generating, re-purposing and consuming content. Web 2.0 significantly varies from Web 1.0 as it empowers the user to create and contribute content, annotate others, assign tags, ratings, and comments; to form online relationships; and to join online communities. Consequently, the Web 2.0 has been able to use social networking sites as a major tool to create a network of users and associate data with each user.

There has also been an explosive growth in the area of mobile communications in the last few decades with exponential increase in Smartphones with data and multimedia capabilities. At present, 90% of the world population is covered by a mobile signal, 128% of the world population has a mobile subscription and in developing countries the subscription rate is 89% (*The World in 2013: ICT Facts and Figures* 2013 ). This has initiated a major change in the Social networking sites, with a majority of them creating Smartphone applications that can interact as clients in their network, which in turn has helped users to share their experience easily through photos and videos.

Researchers and developers are continuously working on transforming the concept of Web 2.0 to provide better and useful services. The information available from different sources across the web along with the information that users provide can be intelligently aggregated to derive useful information that can be provided back to the users in response to their queries. An important aspect of this transformation is to provide efficient access mechanisms to discover and query relevant information. Querying relevant information becomes more challenging if we have to provide personalized information for each user based on their individual requirements.

## 5.1 Social Life Networks

Social Life Networks (SLN) (Jain et al. 2011 ) tries to extend the capabilities of current social networks by combining them with the technological advances made in the last decade. As with Web 2.0, SLN would continue to share experiences among people and connect them to different resources, the resources could be information about material resources, services, and other people. By employing emerging sensor networks combined with participatory sensing by users, Jain and Sonnen (2011) proposes to harness collective knowledge of society to develop SLN for analysing emerging situations and connecting people to appropriate resources for better utilization of resources in normal as well as emergency scenarios. Jain and Sonnen (2011) gives example of effective use of SLN, where spatio-temporal aggregation on information from Twitter can be used to carry out swine flu prediction (Sheth 2009; Signorini et al. 2011; Singh et al. 2010), stock market analytics, and political revolutions.

According to Jain and Sonnen (2011) the world population can be categorized into three distinct classes from a technology driven perspective. Approximately 3 Billion people are categorised by Jain and Sonnen (2011) as the Middle of the Pyramid (MOP) who are not part of the modern Internet in spite of them having access to mobile phones and about half of the world's population falls into the category of the middle of the pyramid. At present, most mobile applications have been developed mainly focusing on the needs of the top 1.5 Billion of the world population. As MOPs are ready in terms of technology and connectivity but has no useful applications at present, developing mobile applications to this segment of the market will open up a new market that is twice the size of the current market (Ginige and Ginige 2011).

Social life networks for the MOP (SLN4MOP) is an International Collaborative research program that aims to provide real-time information to support activities related to livelihood delivered using mobile phone applications targeted to meet the needs of people in developing countries. Thus, the aim of SLN4MOP is to meet the market opportunities identified in the developing world. The approach of SLN4MOP is to provide integrated access to the heterogeneous sources of information, provide personalized rather than generic information, and efficient presentation techniques through mobile-based information systems. The research group has identified that the major requirement for next generation of mobile applications for MOPs is to find the relevant and meaningful information one wants at the correct time (Ginige and Ginige 2011 ). This requires intelligent ways to aggregate information from different source to identify events that are taking place at personal, local, regional and global level. The research group has also identified that these systems should also be capable of receiving information from a large number of users; aggregating this information in near real-time and making this aggregated information available to users (Ginige and Ginige 2011 ). There should be functionality for users to quickly find information in real time to enhance their day-to-day activities.

### 5.1.1 Social Life Networks for Farmers (SLN4F)

In order to test the effectiveness of the task context model in SLN, the first project in SLN4MOP, the Social Life Network application for farmers (SLN4F) in Sri Lanka (Ginige; et al. 2012 ) is used. In Sri Lanka over production of vegetables is a regular problem due to many farmers growing the same crop without being aware of what others are cultivating (Hettiarachchi 2011, 2012 ). To avoid this, farmers need to know the current production levels at the time that they are deciding what crop to grow. This will enable them to decide whether there is going to be a surplus at the time they take the harvest to the market. In Sri Lanka, the island wide agricultural activities are coordinated by Department of Agriculture. Agricultural officers regularly visit farmers and collect information about what has been planted. It takes few months for this information to be aggregated and reported. The extent of cultivated crops is rapidly changing during planting season and cannot be monitored using these manual processes. Thus so far there has not been a successful solution to the problem of overproduction of vegetables in Sri Lanka.

The vision is to develop a high-level knowledge framework based on Social Life Network concept to enable farmers to make an informed decision resulting in minimising the over production situations experienced by farmers at present (Ginige; et al. 2012 ). The proposed solution is based on Social Life Network concept where farmers using a Mobile Based Information System (MBIS) will report the extent of their crop cultivation. This information is then aggregated based on location, time and crop type to derive current production levels for different crops in real time. The aggregated information is made available to farmers who are about to decide what crop to grow. The underlying expectation is that this will enable them to make an informed decision resulting in minimising the over production situations that are experienced by farmers at present. Although the proposed framework is aligned towards requirements for the farming domain, it is generic enough and applicable to any mobile information system that supports the livelihood activities of the people.

The research group identified that farmers need static as well as dynamic information. The static information can be sourced from existing websites and published literature in the agriculture domain. Also the group found that this information needs to be reorganised to be able to present to farmers according to their information needs at the time. The research group also found that generating the dynamic information that farmers need is a challenging task. When farmers are about to decide what crop to grow, they wanted to know how much of a specific crop has been planted by others. They also wanted to know the prevailing market prices for crops in their local market as well as on a regional and national basis. The research group decided in the first instance only to look at a mechanism to show farmers what is the current production level compared to the anticipated demand for a crop variety in real time. The anticipated demand is regularly predicted by Department of Agriculture in Sri Lanka.

The design challenge that need to be addressed to create the identified SLN application was to find a way to provide information in context. This work tries to address this design issue by using the task context model, explained in chapter 4 to represent farmer context when they are searching for information. Using sensory information that can be obtained from mobile devices the physical context needs to be identified and using this farmer context the different data sources need to be queried to find the information that farmers needs, aggregate these and send them to the farmer. Thus this work focuses on the core processing unit of SLN that needs to interact with other modules of SLN. In order to develop this module, the task and procedural knowledge needs to be identified for this domain. The work done by Lokanathan and Kapugama (2012) and De Silva et al. (2012) is used to identify the task and procedural knowledge in the farming domain. In order to filter out the relevant information from the domain knowledge, the work of Walisadeera et al. (2013*b*) who created a structured knowledge repository of static agricultural information in ontology is used. To derive dynamic information the context module needs to interact with real time data sources and the real time aggregation unit. All the interaction with the context module takes place with an interaction environment, so the necessary web-services to communicate with the interaction environment needs to be developed.

## 5.2 Relevance Cycle - Context Analysis in Farming Application

Many researchers have identified lack of information as a major reason preventing farmers from making better decisions (Lokanathan and Kapugama 2012; Parikh et al. 2007; Punchihewa and Wimalaratne 2010 ). The information need varies mainly depending on the stage of the farming life cycle (Lokanathan and Kapugama 2012 ). Researchers have highlighted the inefficacy of the existing information dissemination methods such as face to face communication with agriculture officers, websites and other communication methods such as use of mass media. Information needed by farmers include market prices, current production levels, seasonal weather, best cultivars and seeds, fertilizers and pesticides, information on pest and diseases and their control methods, harvesting and post harvesting methods, and details relating to farming machinery and practices. Some of this information is available from government websites, leaflets, and mass media in several different formats; text, audio, video. Sometimes different terminologies to express the same concept have been used. This knowledge is not reaching the farmers due to unstructured and different formats used, lack of appropriate delivery methods and the general nature of the information.

Glendenning et al. (2010 ) have highlighted the importance of contextualised information and knowledge for the farmers in India. They further explain how effective this knowledge on their productivity and income since this information is more relevant to their farm enterprises and better reflects needs of the farmers. They therefore recommend that the existence of context-specific relevant information should be considered when developing farmer specific applications.

In order to provide context-specific relevant information we need to determine and model the task knowledge in the farming domain by identifying the activities and tasks. The task context would be one of the task that is defined in the task knowledge and selected or performed by the user at run time. The task knowledge allow us to specify the information need of the task context.We also need to deal with the organization of the knowledge in agriculture domain for easy access of information. The task context is combined with the physical context of the farmer to form the procedural context and the procedural context is then used to filter out relevant information.

### 5.2.1 Modelling Task Context in Farming Domain

The activities, task and decision points in farming domain can be identified by analysing the decisions made by the farmers at various stages of farming. This section describes the information need analysis and information flow model for farmers based on the work of other researchers working in the farming domain. The information obtained by analysing these studies helps us to identify the task knowledge for the farming domain.

#### Information Need Analysis of Farmers

In a study done by interviewing farmers in four countries; Bangladesh, India, Sri Lanka and Thailand; Lokanathan and Kapugama (2012 ) have identified 26 different types of information needs across 6 stages of farming as shown in figure 5.1. This report sheds light on the information and knowledge needs in low-income smallholder farms and agricultural micro-enterprises in Bangladesh, India, Sri Lanka and Thailand. The micro-enterprises in the study included traders, collectors and small retailers that sell agricultural produce. The report also explores the use of Information and Communication Technologies (ICTs) and especially mobile phones amongst these micro-enterprises.

### Information Flow Model for Farmers

De Silva et al. (2012 ) has identified that farmers in Sri-Lanka need specific information rather than generic information. For instance, farmers need agricultural information relevant to their situation such as the location of their farmland, their economic condition, their interest and belief, need and available equipments etc. De Silva et al. (2012 ) carried out a causal analysis to determine the factors that influence farmers decision making at various stages of the farming lifecycle and in that process they identified what specific information is required in each stage. The causal analysis was carried out through a series of surveys. In this process, they also looked at the various information sources currently available for farmers following which De Silva et al. (2012 ) determined how the information needs to flow to the farmers. De Silva et al. (2012 ) identified as shown in figure 5.2 crop choosing, growing and selling stages as the key phases that create a direct impact on the farmer revenue. In view of farming domain, revenue is determined by the selling price of the harvest. There are three main price determinants for a specific crop yield. Yield quality, supply and demand. These factors create a huge impact on price fluctuations at the market level,where market is the place where both buyers (demanders) and sellers (suppliers) come together to cater for

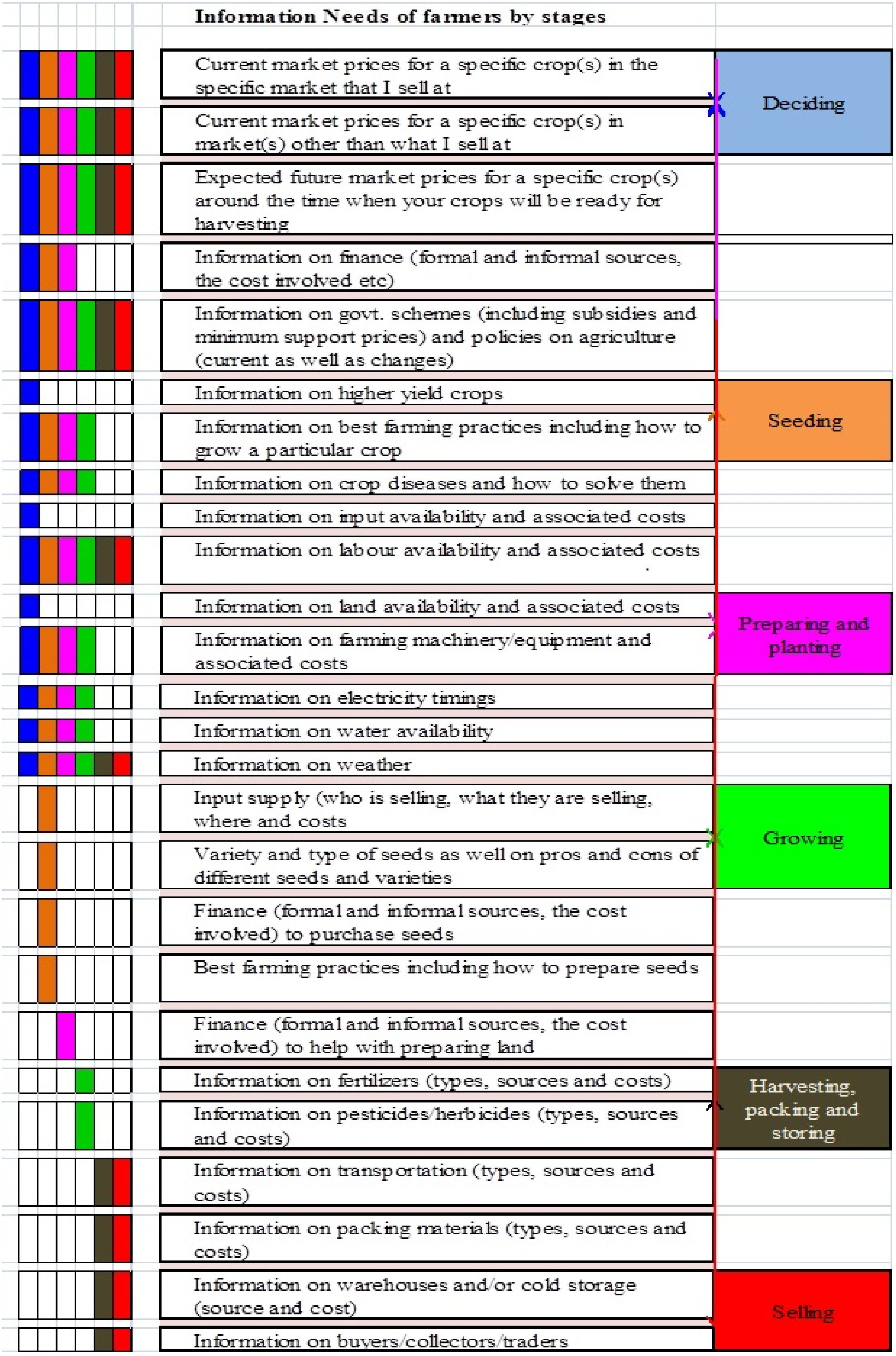



Figure 5.1: Information needs of farmers

each others needs.

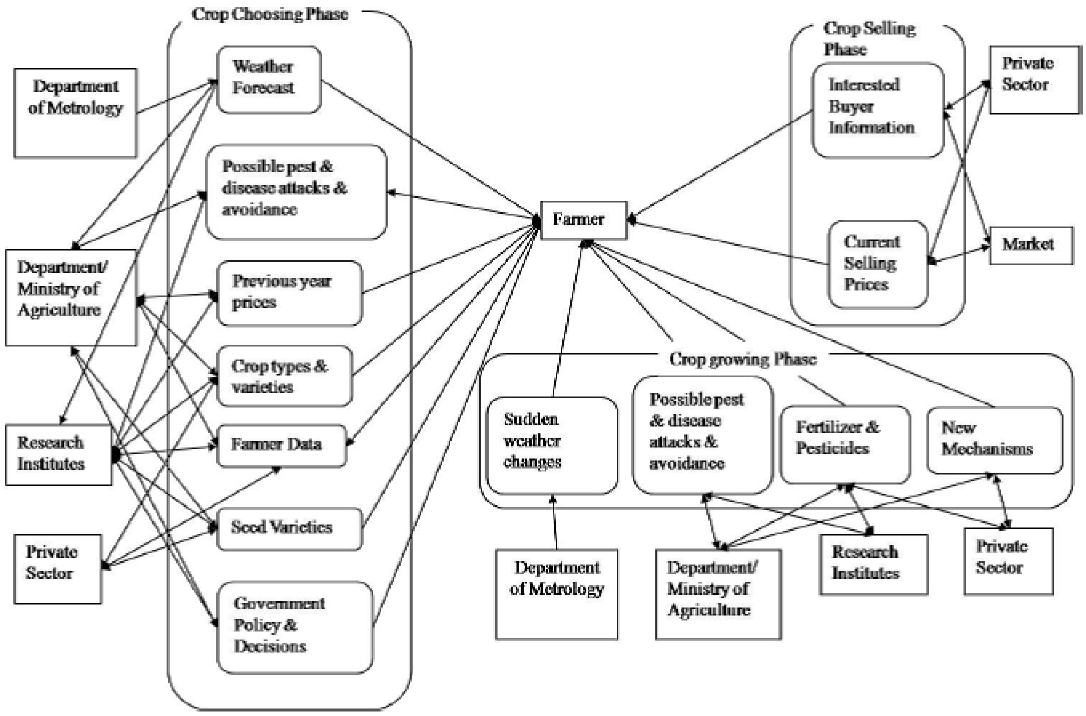



Figure 5.2: Information flow model for farmers (De Silva et al. 2012 )

As illustrated in figure 5.2, the yield quality is determined by weather, pest, diseases, fertilizer, usage of new farming mechanisms and seed quality. Thus, by knowing these factors beforehand would also help the farmer to maintain the quality of the yield. For example, having prior knowledge with regard to seed quality would help farmers to maintain the expected quality of yield at the market level. It thus creates a competitive market in deciding the price of a particular crop. The analysis work done by De Silva et al. (2012 ) highlighted many important issues. The selection of what crop to grow depends on many factors, not only on the current production levels as it appeared on the surface. Farmers are looking at range of factors including issues related to growing the crop as well as selling the crop. They wanted information to support all stages of the farming lifecycle. To make meaningful use of the information, De Silva et al. (2012 ) postulated that the information should be made available to farmers in context and one of the important aspect of that is the stage in the farming cycle.

Thus, it can be seen from the work of De Silva et al. (2012 ) and Lokanathan and Kapugama (2012 ) that the tasks and information need of the tasks, ie the task knowledge is highly influenced by the different stages of farming. By modelling the task knowledge based on the farming stages helps us to better organize the flow of information to the farmer. The different farming stages can be associated with the corresponding tasks and the user interface can display theses stages. When a farmer selects one of these stages, a farmers task context can be identified, and relevant information can be provided to the farmer based on the task context.

### 5.2.2 Modelling Procedural Context in Farming Domain

This section analyses the work done by other researchers on structuring the farming domain knowledge. This information is required to identify the higher level concepts in the farming domain to model the procedural context.

#### Identifying Higher Level Concept in Farming Domain

Deeper information need analysis revealed that the farmers need two types of information; dynamic information such as current extent of crop cultivation, market prices etc. and more stable static information such as crop types, cultivars, suitable pesticides, fertilizer, previous market prices etc (De Silva et al. 2012; Walisadeera et al. 2013*a* ). The dynamic information can be obtained in structured manner in the form of web services and the static information can be expressed using ontology. Walisadeera et al. (2013*b* ) created a knowledge repository of agricultural information to respond to user queries taking into account the context in which the information is needed and because of the complex nature of the relationships among various concepts, an ontological approach was selected that supports first order logic to create the knowledge repository. The agriculture domain knowledge obtained from Walisadeera et al. (2013*a* ), suggests that farm environment, types of farmers, farmers preferences and farming stages are the important factors that needs to be considered for structuring static information. This structuring of the knowledge is required for easy filtering of relevant information, as it helps us to identify the higher level concepts on which the farming domain is structured.

**Procedural Context**

To develop a procedural context for a specific task in the farming domain, we had to first identify the physical context, the higher level concepts in the domain knowledge and the mapping between the two based on the task context. The procedural knowledge is responsible for identifying the source of information. Depending upon the higher level concepts stored in the identified domain knowledge, the procedural knowledge specifies the attributes of the physical context that needs to be captured by the procedural context.For example one of the attribute of the user's physical context that is stored by the system is the geo coordinates. The geo-coordinates can be interpreted in many possible ways like agro ecological zones or administrative districts based on the concepts in the domain knowledge. If the objective of the task context is to determine the environmental attributes of the region then the procedural context can map the geo-coordinates into agro ecological zones otherwise if the objective of the task context is to obtain the market price of the region, then the procedural context can determine under which administrative district the given geo-coordinates belong and then query the appropriate information source to get the relevant data. Thus the task context is combined with the user's physical context to create the procedural context and then the procedural context is used to filter out the relevant subset of information from the domain knowledge.

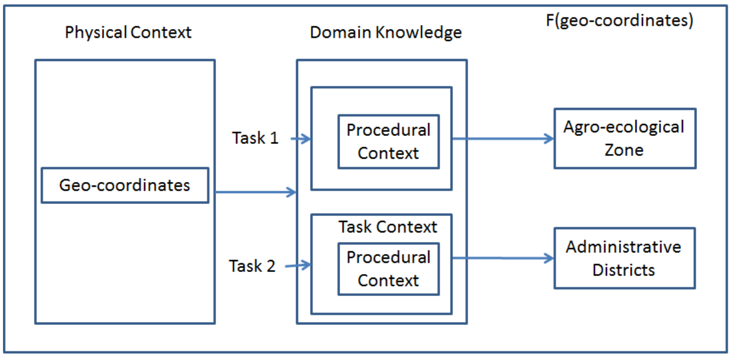



Figure 5.3: Procedural context used to retrieve information from information source

Thus, it can be seen that the same physical context attribute can be mapped into different domain knowledge attribute according to the information requirements of each of the task being performed. So, one of the important capabilities of the context expanding application would be to facilitate this conversion of raw physical data to match the required higher level concepts in the domain knowledge. Different task context uses the procedural context to have space- time-user related information and activities represented different ways which would allow task context to identify and querying different information sources static or dynamic, based on the requirements.

# Chapter 6

# SLN4MOP Application for Farmers (SLN4Farmers)

This chapter presents the architecture for the SLN application along with the detailed physical implementation of the context based content aggregation module. The description of the first version of the mobile prototype for farming domain is also presented and the evaluation of the ability of the prototype to provide relevant information to farmers on crop selection is analysed.

## 6.1 Architecture of SLN Application

Social life network (SLN) application is a mobile based information system that aims to provide relevant information about the task being performed by the user, to help the user make better decision in their profession. The key features of an SLN application is that it needs to have an interaction environment suitable to the needs of the users, a context based module to provide relevant information from different sources, a data manager to manage the static and dynamic information and a user engagement module to motivate and encourage users to contribute. The figure 6.1 represents the modules in a SLN application.

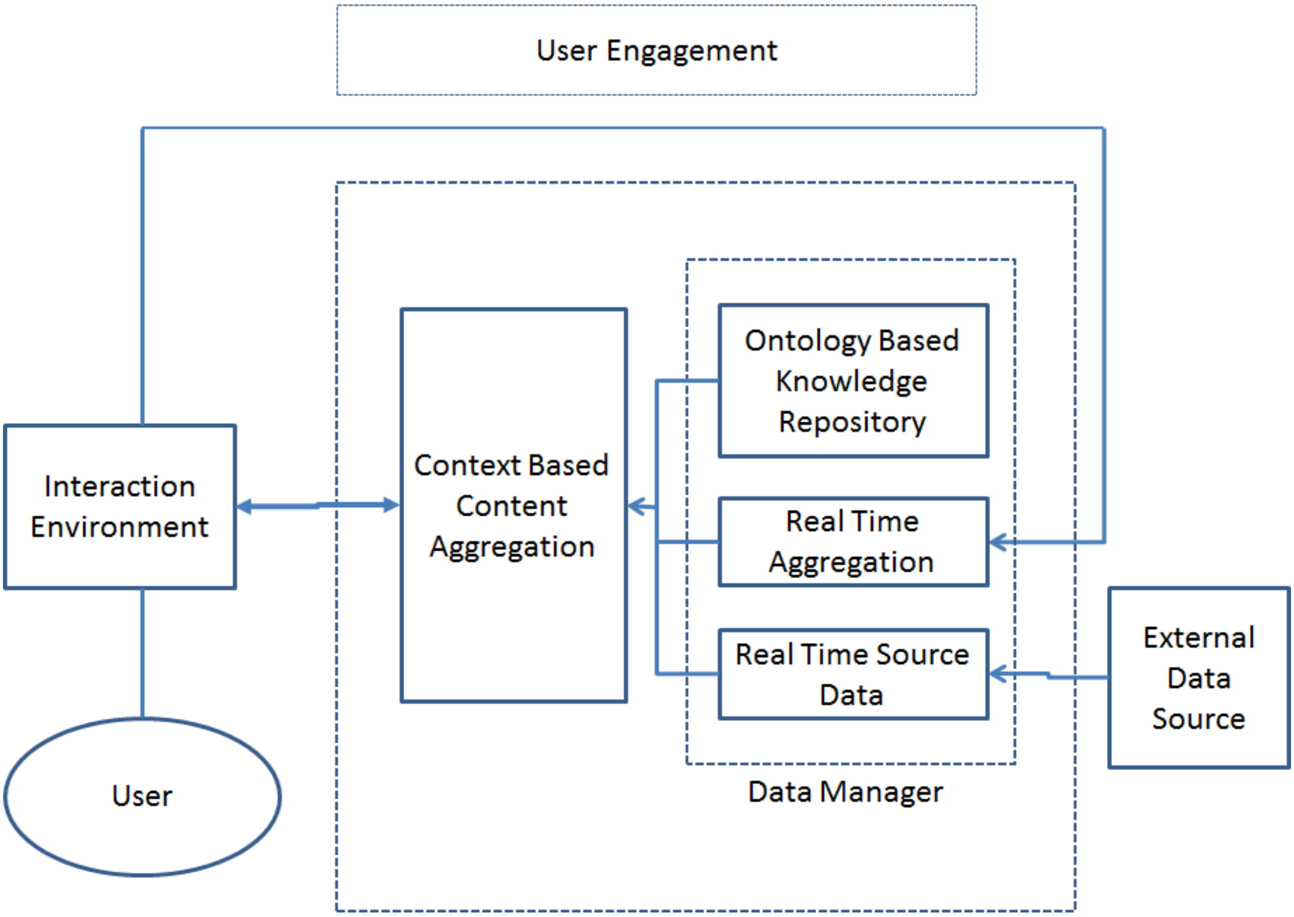



Figure 6.1: Architecture of SLN Application

**Interaction Environment :** Extensive training was required to use the first generation computing environments that were developed for scientists. The interface for main stream applications used in business, education, healthcare, entertainment, and other domains were gradually developed as part of the second generation computing environments (Jain et al. 2011 ). The interaction environments were further developed so that it could be used by educated novices. For the SLN4Farmers application, the interaction environment was designed by Di Giovanni et al. (2012 ), through the investigation of ways to develop a suitable user interface for a Social Life Network application. They used scenario based approach of Sears and Jacko (2007 ) to develop the interface for farmers in Sri Lanka and created some typical personas and interaction scenarios based on earlier survey findings (Di Giovanni et al. 2012 ) and these scenarios were analysed to determine the user interfaces.

**Context Based Content Aggregation :** An appropriate infrastructure for social life networks as shown in figure 6.1 should support most of the tasks required to identify the context. The context based content aggregation module, the main contribution of this work for SLN, needs to focus on a scalable context management. It has the task knowledge, which defines the tasks to be performed and the information requirement for those tasks. The task context is captured when the application is running and it then uses the user's physical context and the procedural knowledge to filter out the relevant information. The users physical context is responsible for keeping the context state updated for each individual user of the application.

The context characterizing properties that change with spatial and temporal attributes is captured by the users physical context model. Thus, the context based content aggregation module provides the following functionality:

- The definition and structure of context models that is used to represent the task being carried out by the specific application.
- The acquisition of data at run time that is used by the context models to

provide personalized information in context.

The detailed implementation of the context based content aggregation component is done in the next section, section 6.2 The context based content aggregation module interacts with other modules of SLN through web-services. The web-services are designed according to the information transfer requirements between different modules. Thus, the context based content aggregation module becomes the central part of the SLN as it connects all the different modules of SLN.

**Data Manager :** Data manager is responsible for reasoning and concept representation. Conceptually the data manager can be grouped into two, ontology based knowledge repository for static information, real time aggregation module for dynamic information and the real time source data available as web-services from external sources. Walisadeera et al. (2013*a* ) has shown how ontology can be used to find a response to queries within a specified context in the domain of agriculture. This structured view is essential to facilitate knowledge sharing, knowledge aggregation, information retrieval, and question answering. The real time source data provides dynamic information such as market price or weather information from external source while the real time aggregation module is used to obtain dynamic knowledge about the prevailing conditions by aggregating micro-information sent by users.

**User Engagement :** The issue of motivating the users to engage with and contribute to the common resource pool has been identified as one of the most important issue and frequently cited bottlenecks (Maia et al. 2008; Nov et al. 2009 ) in social (life) networks (Jain et al. 2011 ). Jain et al. (2011 ) has identified that the factors which can motivate users to contribute to social (life) networks. These factors are:

- Personal intrinsic value creation, where the act of engagement/contribution is the reward in itself i.e. the users are doing it for themselves, for example, for fun or social connection.

- Shared intrinsic value creation, where the act of engagement/contribution is perceived as that of creating a common good for public consumption. The value accrued is available to all at large including the contributors themselves.

- Personal extrinsic value creation, where the act of contribution results in extrinsic personal benefits directly or indirectly.

In the SLN4Farming application, the farmer is motivated to engage with the application. Once the farmer has made a decision on a particular crop, the farmer is given the option of entering his expected produce into the application. The information gathered from different farmers are aggregated by the real time aggregation module to give an indication of current production, where a colour coding scheme is used to visually represent the current production level of the crops. Specific colours (Green, Yellow, Red) were used to represent different thresholds and when it reaches a specific threshold farmers were warned of the danger (highlighted using Red) of selecting the same crop as it may create an oversupply at the market level. The colours were chosen based on the work done by Di Giovanni et al. (2012 ) on user interface. The farmers providing the information about the crop being grown meant that the system now understood which crop was grown by the farmer in his individual farms and thus this information helps the system to create a context about the farmer. Now when the farmer uses the application again, the system would be able to provide additional information required by the farmer for growing the selected crop. This acts as a motivation for farmers to provide the production information.

**Flow of information:** The task and procedural knowledge is captured and used to design the Context Based Content Aggregation module. The task knowledge dictates the interface design of the interaction environment. The procedural knowledge identifies the information source for each task in the task knowledge. When a task is selected, the information is passed on from the interface environment to the Context Based Content Aggregation module through a web-service. The information required for the task is captured from the static or dynamic information source by the Context Based Content Aggregation module, which queries the relevant information source. The dynamic source might also include the output from real time aggregation module depending on the procedural knowledge. The data from the information source is passed on to the Context Based Content Aggregation module as web-services and this information is aggregated and then passed on as web-service to the interface environment.

## 6.2 Context Based Content Aggregation Module

This section describes my contribution to SLN, the different components that needs to be implemented for the context based content aggregation module of the Social Life network application. An activity of crop selection in farming domain has been chosen to explain the implementation of these components.

### 6.2.1 Task context

The first stage in implementing an application in the farming domain that can provide information in context for the farmer is to design the task knowledge.

| **Information needs of Farmers in Crop selection stage** |
|---|
| Current market prices for a specific crop(s)in the specific market that I sell at |
| Current market prices for a specific crop(s)in the specific market(s) other than what I sell at |
| Expected future market prices for a specific crop(s) around the time when my crops will be ready for harvesting |
| Information on Finance<br>( sources formal and informal, cost involved etc) |
| Information on Govt. schemes<br>(including subsidies and minimum support price)<br>and policies on agriculture(current as well as changes) |
| Information on higher yield crops |
| Information on best farming practices including how to grow a particular crop |
| Information on crop disease and how to solve them |
| Information on input availability and associated cost |
| Information on labour availability and associated cost |
| Information on land availability and associated cost |
| Information on farming machinery/equipment<br>and associated cost |

| |
|---|
| Information on electricity timings |
| Information on water availability |
| Information on weather |

Table 6.1: Information needs of Farmers for selecting crops Lokanathan and Kapugama (2012 )

The task knowledge contains all the activities that need to be performed to achieve the goals of the user. When the application is executed, the task context is generated by the user selecting any one of the activities, specified in the task knowledge.Each activity can be further sub divided into tasks and the information needs of each task is identified in the task knowledge. For example, the sub set of information need for a specific task of "Selecting the crop" has been identified through the analysis of the domain by Lokanathan and Kapugama (2012 ) and is shown in table 6.1 which provides the context in which the task is being performed. Thus, each task has a subset of information from the domain knowledge that matches the information needs of the task being performed.

Example: A good example to describe the advantage of using a context aware application would be a situation in which the farmer decide what crop to grow?. In the first stage, the task knowledge for the activity crop selection is a set of tasks that need to be performed along with its information needs. The information need for the first task would be to identify the list of crops that would be most suitable to be grown. The information need for the second task is to identify all the characteristics of each crop in the list. The information need of the next task is to identify the market price of each crop in the list and the information need of the final task is to identify the current production level of each crop in the list. When the application is executed, the task context is "Selecting the Crop".

The above task knowledge can be represented as an array of information as shown 6.2.

```
array('Crop selection' =>
        array(
                'task1'=>'list of crop',
                'task2'=>'crop characteristics',
                'task3'=>'market price',
                'task4'=>'production level',
        )
);
```

Figure 6.2: Physical value of task context

### 6.2.2 Procedural Context

The second stage in implementing an application in framing domain is to design the procedural knowledge. For each task identified in the task knowledge, the procedural knowledge is responsible for capturing the source of the information need of the task. The information source is required to have an organized structure for easy access of information. De Silva et al. (2012 ) has identified that there are two types of information needs in the farming domain, static and dynamic. The dynamic information in the farming domain is structured using web services and the static information of the farming domain is structured based on the work of Walisadeera et al. (2013*a* ) , in the form of an agricultural ontology.

The procedural knowledge is also responsible for identifying the attributes from the physical context that would be used for querying the information source.

The information stored in the domain knowledge would be using higher level concepts of the domain. For example, the location in an agricultural ontology may be represented as agro-ecological zone or the location in a dynamic web-service for market price may be represented as administrative districts. The procedural knowledge is responsible for mapping the physical context attributes to the higher level concept depending on the source from which the information is obtained.

For example, in the case of activity crop selection, for the first task to identify the list of crop, the procedural knowledge first needs to specify the information source. In this instance, the information source is Agricultural Ontology. The physical attributes required to carry out the querying would be location which is the geo coordinate and the time. Now, since the procedural knowledge is aware of the fact that the location stored in the ontology is in the form of agro-ecological zone and the time is stored in the form of agricultural season, the procedural knowledge needs to make sure that the location available from the users physical context as geo-coordinates needs to be mapped into agro-ecological zone and the time available from the physical context needs to be mapped into the agricultural season. When the application is executed, the procedural context would be to use the physical context such as the geocordinate value and the captured value of time, and then map them into higher level concept value such as DL for agrozone and Maha for time. With the mappings done, the procedural context is able to generate the necessary query to obtain the necessary information from the information source. The above procedural knowledge can be represented as an array of information as shown 6.3.

The procedural knowledge is responsible for doing mapping of the geo-coordinates

```
Array
(
   [task1] => Array
      (
         [Source] => Agricultural ontology
         [Requirment] => Array
            (
               [0] => Location
               [1] => Time
            )
         [Mappings] => Array
            (
               [location] => geo to agrozone
               [time] => calendar to farm season
            )
         [Query] => what crop to grow in with agrozone and maha ?
      )
)
```

Figure 6.3: Physical value of procedural context

to corresponding higher level concepts. One of the methods implemented in this work is to use reverse geocoding, using kml files and point in a polygon algorithm.

### Reverse Geocoding

The first step of the approach is to find the location associated with each user, the location could be in the form of districts, agro-ecological zones or some other higher level concept as defined in the information source. This is done by reverse geocoding the coordinates specified in the user's physical context. Reverse geocoding involves mapping a point (latitude and longitude) to some defined region with a place name or identifier. It is the opposite of geocoding, which is the process of converting addresses to their associated geographic coordinates. Any reverse geocoding service could be used to perform this task, and different definitions of location could be considered, including very specific regions such as street addresses.

We used the Keyhole Markup Language (KML), an XML notation for expressing geographic annotation and visualization within Internet-based, two-dimensional maps and three-dimensional Earth browsers. The KML defines the boundary of each region as a polygon. For example, in order to find the relevant market price information for the farmer, we needed to identify the district in which the farm of the farmer was located. We used a kml file of Sri Lanka to identify the boundaries of the different districts in SriLanka. The geo-coordinates stored in the users physical context is located within the boundary of a district by using the algorithm point in a polygon (Niessen 2006 ) . The point-in-polygon algorithm proposed by Niessen (2006 ) programmatically checks if a particular point is inside a polygon or outside of it. It tackles the problem by counting the number of times a line drawn from the point (in any direction) intersects with the polygon boundary. If the line and the polygon intersect an even number of times (or not at all), then the point is outside. If they intersect an odd number of times, the point is inside. As shown in the figure 6.4, the lines drawn from point 1 intersect twice or not at all, because it is outside. Point 2 is inside and thus the lines drawn from it intersect once or three times. Even in special cases, such as point 3, the line intersects twice and the point is therefore outside.

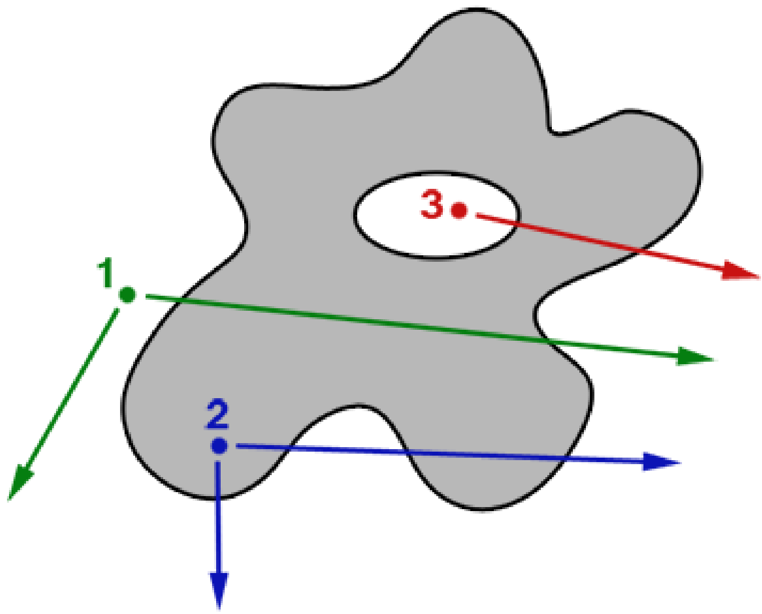



Figure 6.4: Point in polygon theory (Niessen 2006 )

The geocordinates of the farm of the farmer captured using the application was reverse geocoded to obtain the district in which the farm was located. Thus the geocordinates are mapped into the corresponding higher level concept of the information source by the procedural knowledge using the reverse geocoding process and this higher level concept becomes part of the procedural context.

### 6.2.3 Physical Context

The next stage in implementing the farming application is to identify the attributes that needs to be captured for the user's physical context. The generic model of physical context dictates that we need to capture the spatial, temporal and user profile information. The application domain context is responsible for identifying and capturing additional information for the physical context that is specific to a domain.

For example, in the farming domain the farmer might have multiple farms. So the user's physical context needs to capture the location of each farm that is associated with the farmer. Similarly a group of farmer might use the same mobile to access information for their individual farm, so the physical context of the mobile user should be able to capture these domain specific requirements. These domain specific requirements are known as application domain context. The application domain context is used to model the user's physical context for each domain as shown in figure 6.6. The above users physical context can be represented as an array of information as shown 6.5.

```
array('Farm' =>
            array('Geocordinaties'=>' '),
               'time' => ' ',
               );
```

Figure 6.5: Physical value of users physical context

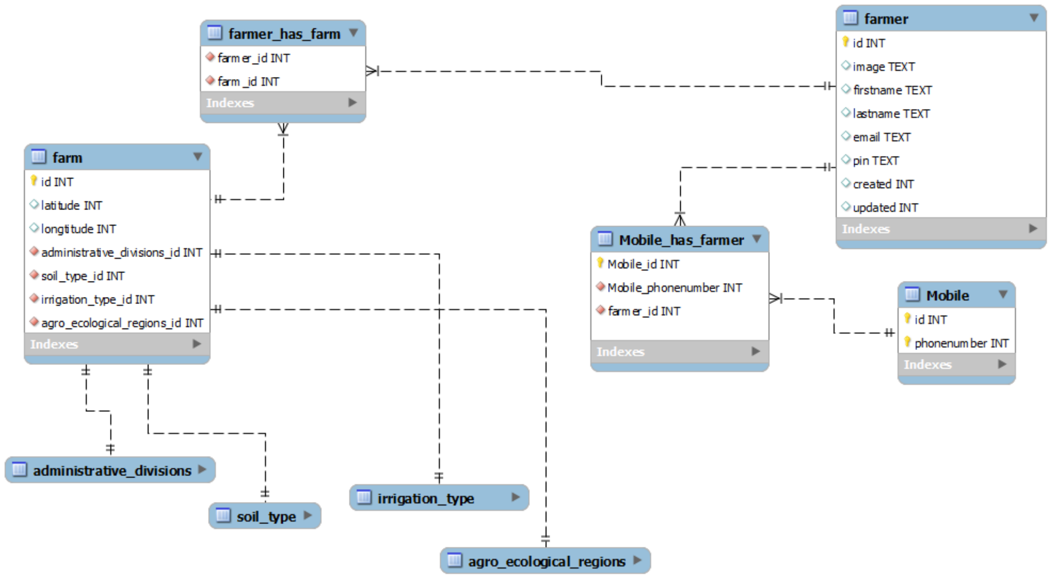



Figure 6.6: ER diagram for capturing users physical context

### 6.2.4 User Interface

Web services were designed to commutate information with the user interfaces developed by Di Giovanni et al. (2012 ). The user interfaces are meant to change with the changing requirements of the user and so the web-services also need to be flexible enough to accommodate the changing interfaces. The web-service were also optimized to meet the efficiency requirements of the mobile application as defined by the designers of the user interfaces.

## 6.3 Running the Application

The farmer selects the appropriate activity from the user interface and then the system identifies, capture or use the existing attributes of users physical context. For example, if the farmer selects the activity as crop selection, the system identifies that farmer is in the first stage of farming and thus only needs to concern itself with the subset of information that the farmer might need at this stage. The users physical context along with the activity is passed on the procedural context module, which process each task of the activity one after another. The procedural context module uses the required attributes of the users physical context, maps it into the corresponding higher level concept of the domain, if required and then generates the query that is used to filter out the relevant data from the domain context. The procedural context module then returns the subset of relevant information. This information is then passed on to the user interface as web-services. The user interface is responsible to display the information to the farmer in an optimal manner. For example, for the crop selection activity, the system provides a list of crops suitable to the farm of the farmer based on the fact that the farm is located in a particular agro ecological zone in Sri-Lanka and therefore a matching can be done to produce a list of crops that could be grown in that ecological zone. This list is further limited by the season in which the farmer intends to grow the crop. Thus the user's physical context is used to limit the information obtained from the domain context based on task context.

The above dynamic run time context can be represented as an array of information as shown 6.7.

```
array(2) {
        ["Activity"]=> string(14) "Crop selection"
        ["User physical context"]=> array(2) {
                ["Farm"]=> array(1) {
                        ["Geocordinaties"]=> string(5) "12,13" ,
                        ["time"]=> string(9) "12/8/2008"
        }
}
```

Figure 6.7: Dynamic value of context at runtime

The procedural context module is also able to interact with the dynamic real time aggregation component of the Social Life Network, which indicates the current production level of each crop. The list of crop returned by the system can then be ranked according to the current production level if that dynamic information is available to the system. To empower the farmers each crop would be associated with vital information, which would then assist the farmers in their decision making process.

In this particular scenario, the system is able to filter, rank and provide information about different crops by identifying the context of the farmer and the task that the farmer was performing. The context of the farmer is dictated by the ecological zone in which the farm is located, the farming stage or the activity that he needs to perform, the season in which the farmer intends to grow the crop, and the personal preferences of the farmer.

## 6.4 Internal Prototypes

The iterative design methodology was used to develop the internal prototypes of the context based aggregation module for the application, in which a systematic and cyclic process of prototyping, analysing and refining of the context module took place.

- In the first iteration, the application domain knowledge was used to develop the use cases for the farming application and the necessary access control was implemented for the context models. The entity relationship model to capture the physical context of the farmer was analysed and then implemented. For the first internal version, the database was used as the information source. The objective of this prototype was to determine if the context model was able to filter out relevant information and the access to this information is allowed only to authorised users based on user roles. In this iteration, parts of the procedural knowledge was implemented. The mapping of physical attributes to higher level concepts in procedural knowledge was not implemented.

- In the next iteration, the focus was on to refine the process of capturing the procedural knowledge. In this iteration, identification and mapping of physical attributes to higher level concepts was implemented. The use of KML files to perform reverse geocoding was achieved in this iteration. The information sources for this iteration was still database. The webservices required to perform the interaction with the interface module was developed, based on the requirements identified by Di Giovanni et al. (2012 ).

- In the third iteration, the information source, database was replaced with an agricultural ontology, the ontology was developed by Walisadeera et al. (2013*a* ) to capture the agricultural domain knowledge. The procedural knowledge was now able to generate queries to ontology with higher level concepts used in the ontology schema and filter out relevant data from the ontology.

- In the fourth iteration, additional feature was added to the context module to support the real time aggregation unit of the farming application. The procedural knowledge had now the capability to interact with multiple information sources and the queries were generated for appropriate information source based on the requirement of each task. The webservice for the interaction model is modified to include information from multiple sources.

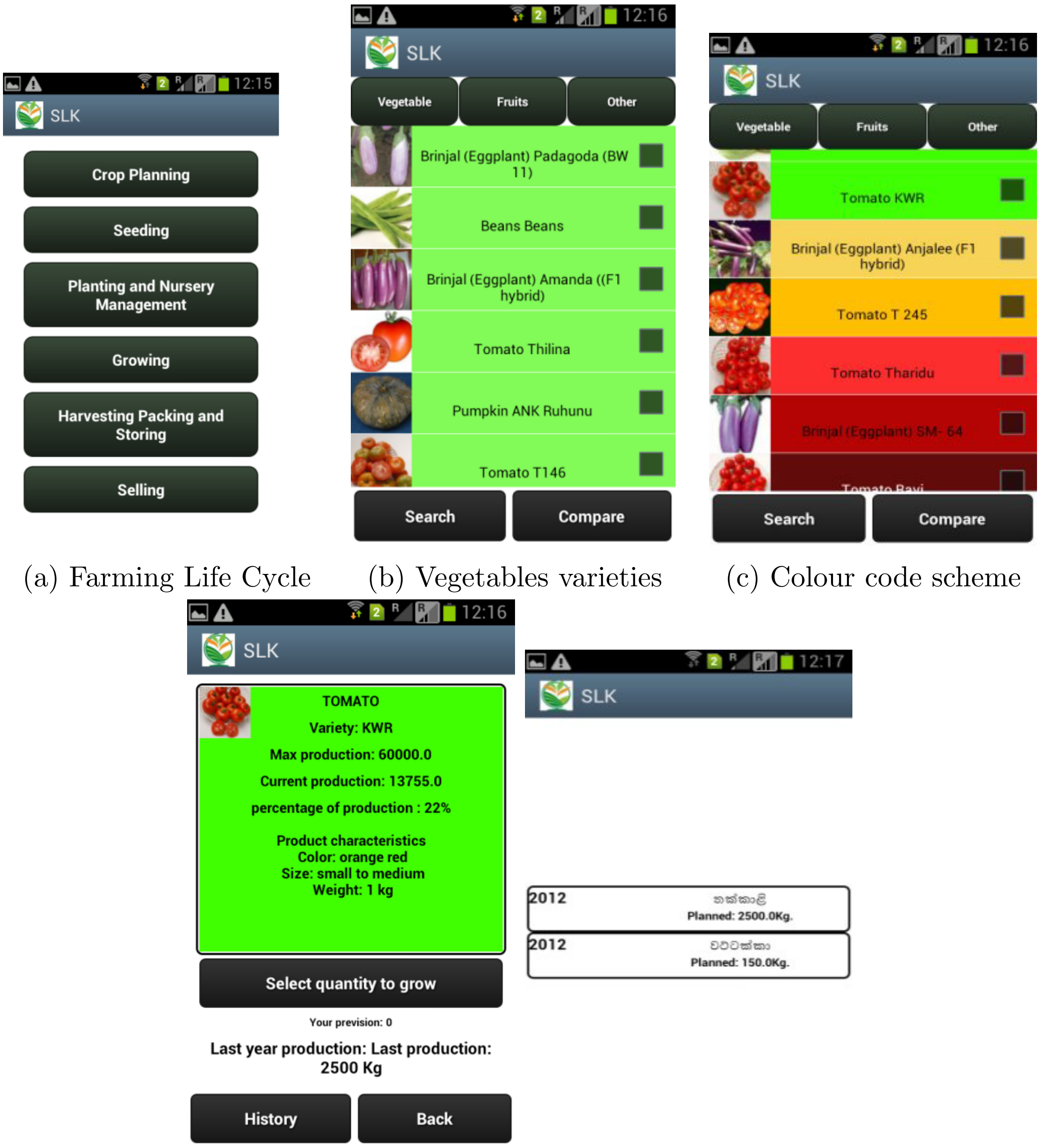
After the four iterations, the first version of the mobile prototype was created and evaluated with a group of farmers.

## 6.5 First Version Mobile Prototype

In our preliminary studies it was identified that farmers need information at the right stage of the farming life cycle to make better informed decisions (De Silva et al. 2012 ). The information need varies mainly depending on the stage of the farming life cycle (Lokanathan and Kapugama 2012 ). Further, it was identified that the way this information should reach the farmer should be made more efficient due to the inefficacy of the existing information dissemination methods such as face to face communication via agriculture officers, web sites and other applications implemented targeting the farming community. The preliminary studies (De Silva et al. 2012 ) and other surveys carried out by different researchers (Lee et al. 2012; Parikh et al. 2007; Punchihewa and Wimalaratne 2010 ) highlighted the need for a systematic approach to address the information gap among the farming community.

To test the concept an end to end prototype was developed. The architecture specified in section 6.1 was implemented as a mobile application for Android phone connected to a back-end server through web services. The initial version of the application based on the preliminary studies focused on the crop choosing stage of the farming life cycle. This initial prototype was evaluated with a sample of farmers to check the usefulness of provided information and usability of the application in order to support their day to day decision making process De Silva et al. (2013 ). Focus was on user interface, usability and acceptance of the system by the end-users. The design process was based on the research done by De Silva et al. (2012 ) and took into account several factors such as users level of literacy, familiarity in using the device, users cultural background, and language beliefs. Scenarios based on (Di Giovanni et al. 2012 ) studies were used to identify a list of non-functional requirements.

The initial prototype and the questionnaire are the main instruments used in this evaluation study. The questionnaire included both multiple choice questions and open ended questions to encourage and capture wide range of answers based on the participant's knowledge. This gave us the capability to capture farmer's ideas freely. One such open ended question was to identify the factors / functionality which attracted the farmers towards using this application. The prototype included a basic login facility to identify the farmer and directed to an interface




(a) Farming Life Cycle (b) Vegetables varieties (c) Colour code scheme

(d) Crop Characteristics (e) History

Figure 6.8: Screenshots of first version of the mobile prototype

where the 6 main stages of the farming life cycle is included as shown in figure 6.8a.

The prototype targeted mainly the crop choosing stage. Thus, only the crop planning functionalities were available in the initial version used for the evaluation. Crop planner function directed the user to the next screen, illustrated in figure 6.8b. It included 3 main categories namely vegetables, fruits and other. These categories were identified based on the preliminary field trials carried out by De Silva et al. (2012 ). Suitable vegetables and varieties were listed based on the region and the season.

A colour coding scheme was used to visually represent the current production level of a crop as shown in figure 6.8c. Specific colours were used to represent different thresholds and when it reaches a specific threshold farmers were warned of the danger (highlighted using Red) of selecting the same crop as it may create an oversupply at the market level. Once the farmer selects a specific crop variety it shows the variety specific special characteristics such as yield colour, weight, length/size etc. Moreover, it also illustrates special statistics (refer figure 6.8d) such as current production and last year production to make farmers aware of the current as well as the last year situation. The image illustrated in figure 6.8e relates to the functionality provided under History. This functionality was included to show what farmer has cultivated or planned in the recent past. Another special feature included in this prototype is the comparison facility of two or more crops.

## 6.6 Evaluation

The evaluation study activities were designed and done by the SLN research group members, with the objective of determining the effectiveness of context models in providing relevant information. The initial prototype along with a set of questionnaire were used in this evaluation study. The questionnaire included both multiple choice questions and open ended questions to encourage and capture wide range of answers based on the participant's knowledge. The participant were asked to perform the task of selecting a crop to grow. The information relevant to the decision was made available for the farmer through the prototype. In order to measure their performance, the starting and the end time were recorded during each task. After performing the tasks questionnaire was given to get their feedback on the initial prototype. The questionnaire was used to assess the issues in relation to the information provided for the crop choosing stage of the farming life cycle and to identify new functionalities that are needed. The objectives and the results of this evaluation was published De Silva et al. (2012 ).

According to the observations in general the initial version was a success as most of the farmers used the mobile device in few minutes and were able to do the activities as instructed by the researchers. According to the farmer response around 56% was attracted to the idea presented using the colour coding scheme. Farmers were bit concern on the accuracy of yield information through this method and the ability to make a correct decision based on the colour code. A percentage around 47% farmers found the information provided with respect to crop types and different varieties very useful for them to continue to use the application. As our initial prototype contains all possible vegetables and their different varieties on the same screen without having a better classification, farmers found it difficult to select or search for the crop varieties that they were looking for. 34% responses were received in favour of the comparison facility and around 25% for the information provided using the functionality history. However, some have also mentioned the importance of showing more information such as the price sold and the issues faced with respect to the selected crops in the previous seasons will add more value to the history functionality. Some mentioned that they were attracted due to the language used and the presentation of information which is clear for any novice users to learn and understand. Similarly, some have liked the application as it provides more valuable information which can be accessed in lesser time and cost.

Further, based on the questionnaire which included questions as listed in Table 6.2 was evaluated on a liker scale; strongly agree (SA), agree (A), moderately agree (M), disagree (D) and strongly disagree (SD). To better visualize the responses the percentages recorded under SA and A, D and SD were aggregated and based on figure 6.9 the above claims were further verified.

| | |
|---|---|
| 1 | All information for the crop choosing stage is provided |
| 2 | Information is sufficient for decision making |
| 3 | Provide knowledge on different crop varieties |
| 4 | Knowledge on history is important |
| 5 | Market prices of the previous year are important in deciding a crop |
| 6 | Crop comparison facility is essential in deciding a crop |
| 7 | Information provided using the Colour code is clear |
| 8 | Colour code usage is important in deciding a crop |

| | |
|---|---|
| 9 | Functionality provided in this system can be easily learnt by anyone |

Table 6.2: Interview Questions based a 5 liker scale

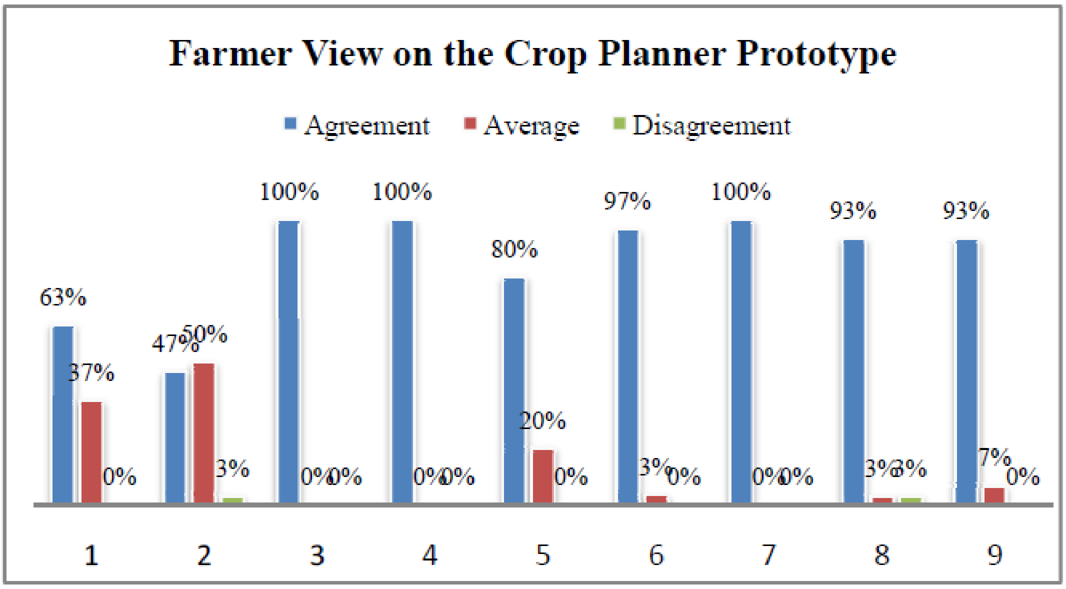



Figure 6.9: Farmer view with respect to the Farming Application Prototype

It was identified that farmers do consider different factors when choosing a crop during the first stage of cultivation. Despite crop knowledge presented in the prototype not being complete, almost all of the farmers were willing to use the system, as they acknowledged the ability of the application to help them make better decisions based on the information provided by the application. They have mentioned that this will add new knowledge to their limited experience to enhance their farming activities. Ability to acquire knowledge at any time from any place was the benefit that they have seen from this type of technology when compared to other existing approaches.

In total 63% of the farmers agreed that the initial prototype has covered the basic information needs at the crop choosing stage. Rest expected more information related to crop variety and seeds. They also agreed that this information is essential knowledge during this stage of farming life cycle which they lack in current practices.

### 6.6.1 Web Service Optimization

The web services are the integral part of the context based content aggregation component as it is the input and output format used to interact with the user interface. Based on the evaluations, design improvements were identified for web-services, as it was identified that the web-services should be based on the requirement of rate at which data needs to be transferred. In the initial stages of application development, all the information about the crop was passed on to the user interface, but it was seen that when the same user returns to the application, the static information did not change as much as the dynamic information. So sending all the information through one web-service for a particular crop seemed to be unnecessary and so the web-service was split to accommodate the option to allow static and dynamic information to be updated separately. This significantly improved the performance of the application on the mobile.

# Chapter 7

# Conclusion

This work was set out to explore the concept of providing relevant information to users in context to support them in achieving the goals of their profession. The case study involved designing of context model in farming domain, to develop an application based on the concepts of SLN, to meet the information needs of farmer to support their livelihood activities. This work sought to answer the research question How to identify the factors specific to a domain and provide information in context for the user ?.

In order to answer the research question, this work sought to answer three of these investigative questions:

1. What is an effective model to represent user context in a domain?
2. How to identify and capture user context from sensory and user action?
3. How to query the different information sources and aggregate that information based on context?

The main findings are chapter specific and were summarized within the respective chapters: 4, 6 and 7. This section will synthesize the findings to answer the studys investigative research questions.

1. What is an effective model to represent user context in a domain?

   The effective model to represent a user's context in a domain is to identify the task that is required to be performed by the user. This model was then used to provide the information relevant to the user performing that task. This work used the farming domain as a case study to evaluate the effectiveness of context models. An application in farming domain was developed with a context based content aggregation module and section 6.6 provides the empirical evidence that the farmers found the application to be effective in providing relevant information.

2. How to identify and capture user context from sensory and user action?

   As explained in section 4.3.2, the physical context model captures the context of the user by capturing the current situation associated with the user. The situation of the user has temporal, spatial and profile attributes which are captured and updated at run time from the sensory device of the mobile. The user's action is captured by identifying the task for which the user needs the information. The identification of the task of the user is important, as explained in section 4.2.5, which reduce the information requirement of the user. The current task is identified by the farming application based on the user interaction in the user interface part of the application.

3. How to query the different information sources and aggregate that information based on context?

The information sources are identified by analysing the work done by researchers who have identified the tasks and information needs of the user for the domain. Based on the requirement of the user's task the identified information source is queried using the context of the user and the personalized information is retrieved, aggregated and provided as web-services for the consumption by the user interface. As explained in 4.2.3, the procedural knowledge contains the information about the information source and the higher level concept used for structuring information in the information source. If the physical context parameters are different from the higher level concepts used to filter out relevant information, the procedural knowledge is responsible for identifying those parameters of the physical context which needs to mapped into higher level concepts. This has been explained in detail in section 4.2.5.

## 7.1 Research Check-list

The design science research methodology is used for this work as explained in chapter 3, the 2004 MISQ paper (Hevner et al. 2004 ) have been largely accepted as integral to top quality design science research, based on which a more specific check-list of questions has been provided to evaluate the design research project. The table 7.1 provides answers to the eight questions of the Design Science approach and associates each question to the chapters in this work where they are satisfied along with a short description.

| Questions | Chapters | Short Description |
|---|---|---|
| What is the research question (design requirements) ? | Chapter 1 | The research question ”How to identify the factors specific to a domain and provide information in context for the user ?.” is introduced in the first chapter of the thesis. This main research question is further divided into three parts:<br>• What is the optimum model to represent user context in a domain?<br>• How to identify and capture user context from sensory and user action?<br>• How to query the different information sources and aggregate that information based on context? |
| What is the artifact? How is the artifact represented? | Chapter 4, 6,7 | The artifacts, which addresses the research issue is the task context model, and a physical implementation of the model is done to verify the effectiveness of the model. |

| | | |
|---|---|---|
| What design processes (search heuristics) will Be used to build the artifact? | Chapter 3 | The iterative design process was followed which would be very similar to the one followed for internal cycles as explained in section 6.4. The first version of the prototype for the mobile application was developed. The evaluation has lead to the identification of the fact that the provided information was not enough and more information has to be provided to make the decision on crop selection. Also, the evaluation of data transfer on webservices has identified the need to have different webservices for dynamic and static information. These changes would be incorporated into the next version of the application along with the other requirement specifications. |
| How are the artifact and the design processes grounded by the knowledge base? What, if any,theories support the artifact design and the design process? | Chapter 2,4 | The advantage of using context in retrieving information in the farming domain have been reviewed.The context modeling has been modeled on the work of Pomerol and Brzillon delimiting the context into into three intertwined spaces. |

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| What evaluations are performed during the internal design cycles? What design Improvements are identified during each design cycle? | Chapter 6 | A systematic and cyclic process of prototyping were done to add the identified requirements and features to the context module. There were four internal iterations before the first version of mobile prototype was developed. The section 6.4 explains each of these cycles in detail. |
| How is the artifact introduced into the application environment and how is it field tested? What metrics are used to demonstrate artifact utility and improvement over previous artifacts? | Chapter 6 | The research work has been done by SLN research group members and the result was published (De Silva et al. 2012 ).The evaluation process involved farmers performing the task of selecting the crop based on the information made available by the prototype of the farming application. The evaluation was done using questionnaires and about 63% of farmers found that the application was able to provide relevant information which helped them to make better decisions. |

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| What new knowledge is added to the knowledge Base and in what form (e.g., peer–reviewed literature, meta–artifacts, new theory,new method)? | Chapter 4 | Task based context model identifies the different knowledge types and context models required to develop an application that could provide relevant information for making better decisions on the task being performed based on the context in which task is being performed. An initial concept of this idea was published (Mathai and Ginige 2013 ), in which the focus was to identify the physical context models and the mapping required for higher level concepts in the domain. |
| Has the research question been satisfactorily addressed? | Chapter 7 | The answer to the three investigative question has been answered by the proposed Task based Context model that could provide relevant information to users based on the context in which they perform their task. A detailed description of the research question and answers can be seen in the introductory part of Chapter 7. |

Table 7.1: Design Checklist

## 7.2 Summary and Future Work

To understand the research challenges and to derive possible solutions to provide context based information in Social Life Networks, we have taken a concrete example in the form of an application for farmers that could meet the information needs within the farmers context. To represent information in context, we have developed an approach to model user's physical context and carried out the mapping to obtain the context required by various information sources based on the current attribute values of the physical context. The context based content aggregation module of the application was responsible for facilitating the conversion of raw physical data to match the higher level context of information source and was used to filter out the relevant information based on the information needs of the users task.

The context models proposed in the study was applied to a chosen case study in the farming domain, in which the initial version of the application based on the preliminary studies focused on the crop choosing stage of the farming life cycle. This initial prototype was evaluated with a sample of farmers to check usefulness of provided information and usability of the application in order to support their day to day decision making process. The sample group strongly endorsed the various aspects of the prototype application and provided valuable insights for improvement.

The solution described in this work have been tested by creating a mobile application which has allowed us to prove that the solution is feasible and meets the information needs of farmers in Sri Lanka. In the future we plan to improve the context expansion module by inferring the intent of the users from their interactions with the system (Deufemia et al. 2013 ). The current application is a specific instance of the SLN project and we plan to create more application for SLN to test and refine the context model.

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