Towards an Agriculture Knowledge Ecosystem: A Social Life Network for Farmers in Sri Lanka

Athula Ginige[1], Lasanthi De Silva[2], Tamara Ginige[3,4], Pasquale Di Giovanni[5], Anusha I. Walisadeera[1,2], Maneesh Mathai[1], Jeevani Goonetillake[2], Gihan Wikramanayake[2], Giuliana Vitiello[5],Monica Sebillo[5], Genoveffa Tortora[5], Deborah Richards[4], Ramesh Jain[6]

1 University of Western Sydney, Australia, {A.Ginige, Maneesh }@uws.edu.au,
2 University of Colombo, Sri Lanka,{lnc, jsg, gnw }@ucsc.lk, waindika@cc.ruh.ac.lk
3 Australian Catholic University, Australia, Tamara.Ginige@acu.edu.au
4 Macquarie University, Australia, deborah.richards@mq.edu.au
5 University of Salerno, Italy, {pdigiovanni, msebillo, gvitiello, tortora }@unisa.it
6 University of California, Irvine, USA, jain@ics.uci.edu

Abstract
We have developed and successfully trialled a Social Life Network (SLN); a Mobile Based Information System to support farming activities in Sri Lanka. It provides information required to support activities such as crop selection and cultivation planning in the context of farmer, farm location, season and task being performed. The system also provides a facility for farmers to sell farming related products and services to other farmers. The final system architecture evolved through a series of iterative relevance and design cycles based on Design Science Research methodology. In the first relevance cycle we identified farmer information needs, their current decision making patterns, and some possible ways to enhance their decision making process. In the first design cycles we developed the initial prototype to visualise a possible solution and in subsequent cycles a crop ontology to reorganise published crop information that would be queried in context and processes to empower farmers. Next we went through 2 cycles of creating functional prototypes, field testing with farmers and improving these to arrive at the final system. We noted that this system can enhance the flow of information in the agriculture domain by aggregating or disaggregating information produced by some stakeholders to be consumed by others. Based on this observation the overall architecture was reconceptualised as a Digital Knowledge Ecosystem.

Keywords: Social Life Networks, Design for Empowerment, Agriculture Knowledge Ecosystem

Introduction

Rapid Growth of mobile usage has enabled us to explore new solutions to problems people are facing in their livelihood activities (Boulos *et al.* 2011; Froumentin and Boyera 2011; Ginige and Ginige 2011; Standage 2009). One such problem in Sri Lanka is over-production of vegetables due to many farmers growing the same crop in the same area without having an awareness of what others' are growing (Hettiarachchi 2011; Hettiarachchi 2012). In Sri Lanka the number of Cellular Mobile Subscribers at the end of March 2012 was around 91.3% of the total population (Telecommunications Regulatory Commission of Sri Lanka 2012). Inspired by the rapid growth in mobile phone usage in Sri Lanka and the user empowerment provided by Social Networking applications such as Facebook and Twitter, we decided to explore a possible mobile based solution to address this problem (Ginige 2011).

Social networks provide us with tools to share our experiences using text and a variety of other mediums (Giles 2010). The ways users can participate in these networks have significantly changed as a result of the second generation of Web applications known as Web 2.0. These applications allow users not only to view content but also to add content. Thus users who were previously passive information consumers have been empowered to become information producers facilitating effective two way flow of information (Cormode and Krishnamurthy 2008). Jain and Sonnen (2011) have shown that it is now possible 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 this information available to the users in real time. These networks extend the information sharing concept in Social Networks and are called Social Life Networks (SLN).

We first conceptualised a possible solution to the over production problem based on SLN concept where farmers will be using a Mobile Based Information System (MBIS) to 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. This aggregated information is made available to farmers who are about to decide what crop to grow to guide their selection.

The rest of the paper presents insights we obtained by reviewing related literature, implementation of the conceptual solution using an iterative design approach, how we modified the system based on user feedback, the final architecture and functionality of the MBIS. Next we present a re-conceptualisation of the overall system as a Digital Knowledge Ecosystem.

Mobile Applications for Agriculture

The above conceptualised SLN based solution depends very much on farmer participation to be able to get a reasonably accurate prediction of the amount of crops being cultivated in real time. Therefore when we were reviewing various mobile applications that have been developed to support farming activities we paid special attention to strategies that have been included in the design to increase farmer participation.

Numerous projects have been launched to support the farmers in developing countries including: MFarm platform in Kenya that links farmers and buyers with up-to-date market information and agriculture trends (mFarms 2013), Farmforce (2013) a mobile-based software solution to manage and improve smallholder marketing ability, e-Choupal project in India that delivers farming information to farmers' mobile phones (Radhakrishna 2011), 8villages business project in Indonesia that delivers information to farmer's mobiles using the social network concept (Vaswani 2012), and Rural and Agricultural Development Communication Network (RADCON) project in Egypt that uses an interactive community-based information network to meet the information and communication needs of rural farmers (UNICEF 2011).

Many beneficial results have been observed from these projects but none of these have provided a holistic information flow model nor explicitly investigated ways to motivate the targeted users. In this regard Hoegg et al (2006) have shown rapid growth in user participation in social media such as Facebook, Wikipedia, MySpace can be attributed to communication and collaboration patterns and the way information is consumed and produced in these applications.

Research Approach and evolution of the System Architecture

Since our aim was to design an artefact; a mobile based information system for farmers, we selected Design Science Research (DSR) methodology. DSR can effectively guide the design and capture the knowledge created during the design process (Hevner and Chatterjee 2010). It consists of three cycles; Relevance, Design and Rigor. Starting from the Relevance Cycle the researchers can move around these cycles creating and validating the artefact.

Relevance Cycle1 – Application Domain Analysis

To gain a broader understanding of the problem, we reviewed related literature, conducted surveys, interviewed farmers and agricultural officers. Many researchers have identified that farmers are unable to make informed decisions due to lack of access to accurate and timely information (Lokanathan and Kapugama 2012; Parikh *et al.* 2007; Pavitrani *et al.* 2011; Punchihewa and

Wimalaratne 2010). The information need varies mainly depending on the stage of the farming life cycle (Lokanathan and Kapugama 2012). Glendenning et al. (2010) have highlighted the importance of contextualised information and knowledge for the farmers in India and how such information has increased the productivity.

We surveyed farmers to better understand the factors that influence their selection of crop(s) to grow (De Silva *et al.* 2012) as well as their familiarity with technology. Results showed that 92% of the farmers owned a mobile phone and nearly 50% of them used it to obtain market information. Over 75% farmers stated that there was no proper mechanism for them to get the required agricultural information on time.

Based on the data collected we prepared a causal map shown in Fig. 1 to obtain a deeper view of the problem domain. We have identified crop choosing, growing and selling stages as the key phases that create a direct impact on the farmer revenue. From the causal map we identified how crop yield, yield quality, and supply and demand impact on price fluctuations at the market level. The above analysis 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.

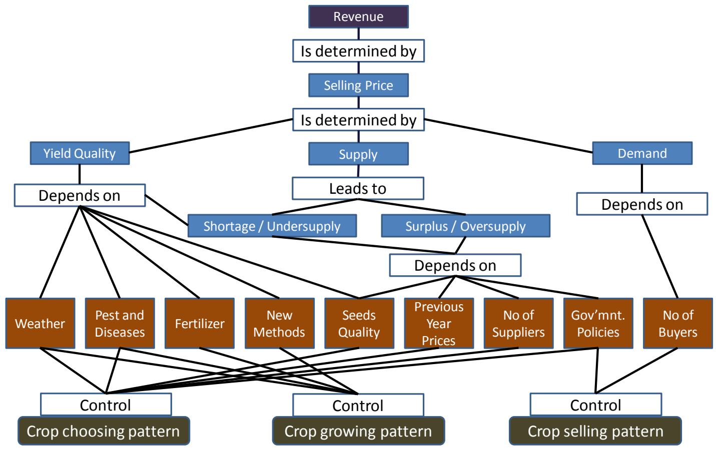

Fig. 1 Factors affecting crop choosing, growing and selling patterns.

Design Cycle 1 – Visualising the Conceptual Solution

The aim of the first design cycle was to visualise the physical form of the conceptual solution that we formulated at the start. We used the scenario based approach of Rosson and Carrol (2002) to design the first set of interfaces. In this approach we created a set of typical scenarios and personas of actors based on data gathered from the surveys (Giovanni *et al.* 2012). Next we investigated how information deficiencies in these scenarios can be mitigated by providing missing information compared to information needs identified in the causal map shown in Fig. 1 and created a set of transformed scenarios. Based on original scenarios and personas we also identified the usability requirements. We used transformed scenarios and usability requirements to develop the first set of user interfaces. The first screen represented a crop catalogue as shown in Fig. 2. We used icons to describe crops and a coloured background to indicate the approximate quantity of each crop already in production. The colour scale ranges from white indicating zero production to red indicating intensive production.

After selecting a crop, users can navigate to the interface shown in Fig. 3 to obtain a more detailed description of the product. We provided check box items to allow users to insert information about the quantity of crop(s) that they want to cultivate to eliminate typing errors. This information is aggregated to derive the current production levels in real time and used to decide the colour codes for crops in the crop catalogue. This design gave the whole research team a good idea about how information can be visualised and user input can be captured.

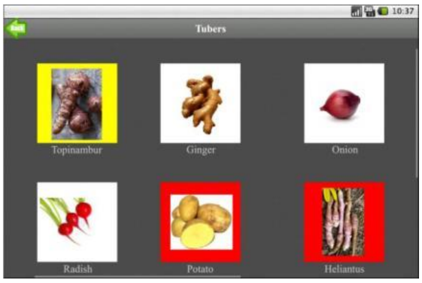

Fig. 2 The crops catalogue.

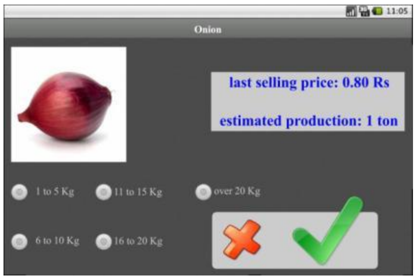

Fig. 3 Product selection interface.

Design Cycle 2– Ontological Knowledgebase Development

In the 2nd iteration of the design we extended the system to provide the information required to support decision making at various stages of the farming life cycle. During the Relevance Cycle we have identified the need to provide this information in context (Glendenning et al. 2010). We first interviewed agriculture experts, reviewed research articles and books (Decoteau 2000; Narula and Nainwal 2010) and authoritative online data sources to identify information required by farmers.

We identified that farm environment, types of farmers, farmers' preferences, and farming stages are the important factors that need to be considered when responding to the above information needs. This forms the user context model. To suit the identified information needs and the context model we developed a crop ontology for farmers in Sri Lanka (Walisadeera *et al.* 2013a; Walisadeera *et al.* 2013b). As we need to query this ontology based on farmer's context we could not use any existing agricultural ontology for this. A high-level view of the developed agriculture ontology is shown in Fig. 4.

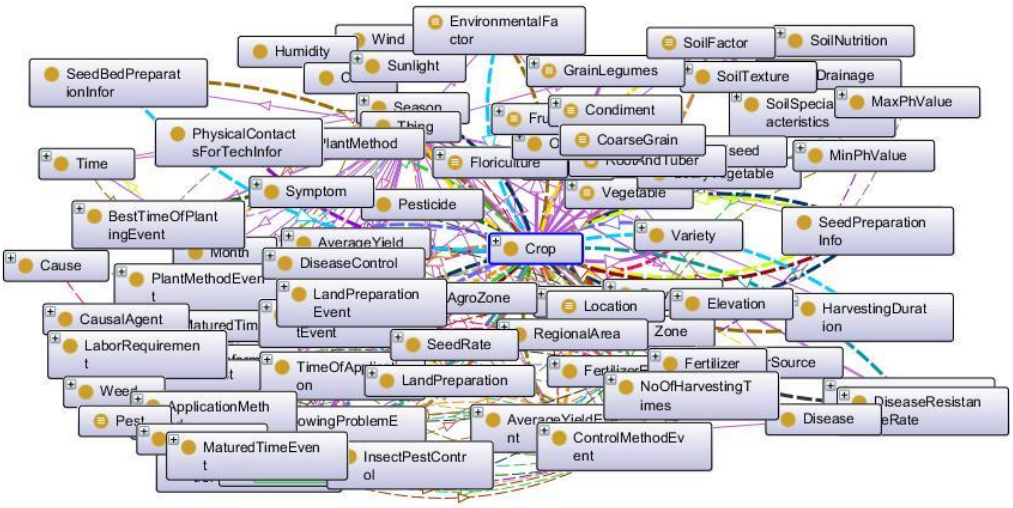

Fig. 4 High-Level View of the Crop Ontology.

We implemented the user context model by identifying the physical and logical context, and the mapping between them. For example one of the attributes of the physical context is the geo-coordinates of a farm. The geo-coordinates can be mapped to logical context in different ways. If the requirement is to determine the environmental attributes to decide what crops will grow in the farm then the geo-coordinates need to be mapped into agro-ecological zone, but to obtain market prices the mapping should be to corresponding administrative district (Mathai and Ginige 2013).

Design Cycle3 – User Empowerment

When reviewing agriculture domain mobile applications, we have identified that most of these applications lack user empowerment. Cornell Empowerment Group (1989 P2) has defined empowerment as "a process where individuals learn to see a closer correspondence between their goals and sense of how to achieve them, and a relationship between their efforts and life outcomes". Therefore empowerment can be viewed as a process for achieving their goals.

One of the goals that we have identified for the farmers was for them to have financial security. Based on the causal analysis shown in Fig. 1 we have identified that farmers make important decisions at key phases of a crop cycle such as crop choosing, growing and selling with the revenue in mind. In some recent ICT applications developed to support farmers, calculators have been included as part of the application. For example, Farmbook is a basic business planning tool and profitability calculator that enables farmer to register to the application, build business plans and evaluate the profitability of specific products in their business plans (Ferris 2011). Therefore we developed a profit calculator as one of the modules in our system. It guides farmers to input cost of seeds, fertiliser, pesticide, labour, machine hire etc. and also the expected harvest and price that they intend to sell the harvest. The calculator then displays the total expenses, expected income and the profit empowering farmers to select a crop that will maximise their revenue (Ginige and Richards 2012).

Design Cycle 4 – Generating Dynamic Content

As the original intention of this project was to address the over production problem it was essential to be able to inform farmers of the current extent of cultivation. In the previous design cycle the profit calculator was designed so that farmers need to specify the type and extent of cultivation to calculate the expenses. By aggregating this information on a spatial basis we can compute the current production level for each of the crops in a region and the total for the country using predictive algorithms in real time.

Design Cycle 5- First Functional Prototype

We created the first functional prototype by combing the artefacts designed in various design cycles. We organised the functionality into 3 modules; "Login", "Crop Selection" and "Profit Calculator".

*Login Module:*As information needs to be customised to suite the context of each farmer we added farmer registration to identify individual users. During the farmer registration stage the user needs to provide the location of the farm by showing it on a map so that geo-coordinates can be captured.

Crop Selection: Farmers can use the system to query what crops will grow in their farm. To respond to this query geo-coordinates based on the farm's location captured earlier will be used to identify the corresponding agro-ecological zone. Based on the agro-ecological zone we can obtain the related environmental factors such as temperature, rain fall, soil type, etc. relating to the farm. Using this information we query the crop ontological knowledge base to find a list of crops that will grow in that particular farm and show the crop list colour coded based on current production level.

Profit Calculator: As described in Design Cycle 3 the profit calculator presents a series of screens to input the various items that are required to cultivate the selected crop, the amount and unit price (if many crops are selected, the calculations are done one crop at a time). It then computes the total cost. The farmer can also input the expected yield and market price to obtain the expected profit.

Relevance Cycle2 – First Prototype System Field Trial

This prototype was field trialled in December 2012 in a main vegetable producing region in Sri Lanka with 32 farmers. We found 56% of the farmers were attracted to the idea presented using the colour coding scheme. Around 47% of the farmers found the information provided with respect to crop types and different varieties very useful, but wanted more details about crop characteristics. Some farmers mentioned the importance of showing more information such as the price sold and the issues faced in the previous seasons highlighting the need to maintain historical data.

We found only about 50% of the farmers systematically calculated the intended cost of the planned cultivation for the coming season. All the farmers had an approximate idea about what their net revenue might be. Around 81% of the farmers mentioned that having a better understanding of their expenses in the various stages of the crop cycle and an awareness of different suppliers may help them to better manage their expenses.

Revised Design and 2nd Field Trial

We analysed the findings in detail and refined the application accordingly (De Silva *et al.* 2013; Ginige and Richards 2013). The information provided during the crop selection stage is enhanced by extending the Ontology to include more details about the varieties and some common diseases. The profit calculator evolved into a comprehensive “Cultivation Planning Application” with a built in expense calculator and expense history module. Once a farmer selects a crop we queried the crop ontological knowledgebase to obtain the required fertiliser and pesticides and the recommended quantities. We further added a Farm Supplies database into the system to show the farmers the potential suppliers and the prices. In order to provide the additional crop information as well as associated fertiliser and pesticide information in the context of farm environment, the crop ontology was significantly expanded (Walisadeera *et al.* 2014).

After making the above changes the prototype system was field tested at 3 locations in Sri Lanka in November 2013 involving 50 farmers. Farmers were very happy with the extended functionality. We observed some usability issues relating to gestures farmers are using to interact with the Smartphone. Also we became aware that farmers produce seeds and fertiliser; especially organic fertiliser to sell to other farmers. Sometimes they also hire out labour and farm equipment such as hand tractors etc. to others.

Refined Architecture and Overall Operation

Based on the 2nd field trial findings we further refined the system. In order for farmers to be able to sell their seeds and, fertiliser and to hire out labour and equipment we added a new module “My Offerings” to the existing modules. Farmers can enter products and services that they would like to offer through this module to the system and this information becomes visible to other farmers when they are using the expense calculator in the Cultivation Planning Application. We hoped this would facilitate the creation of a local market to further empower farmers.

During the re-design phase we found all 3 major application modules “Crop Selection”, “Cultivation Planning” and “My Offerings” can be mapped in to four common architecture layers; “Aggregation/Disaggregation”, “Information Flow and Storage”, “User Empowerment Processers” and “User Experience”. This layered architecture and core functionality are shown in Fig. 5.

The *“Aggregation/Disaggregation Layer”* contains a predictive algorithm module to aggregate cultivation extents provided by farmers to predict expected total production. It also contains the crop ontology which disaggregates and re-organises published agriculture information to be able to query in context by various applications and store these in Crop Ontology Knowledgebase.

The *“Information Flow and Storage Layer”*contains User Data, Production Data, Crop Ontology Knowledgebase and Farm Supplies Data. This layer can be designed by analysing information flow patterns in the domain. Farmers need crop knowledge which is stored in the Crop Ontology Knowledgebase. Using this information farmers decide what crops to grow and provide the planned extent of cultivation. This information gets stored in the Production Database. Once this information gets aggregated the predicted values also get stored in the same database. The Farm Supplies database contains what commercial suppliers offer as well as what farmers offer to other farmers as products and service required for cultivation. User profile and farm information are stored in the User database.

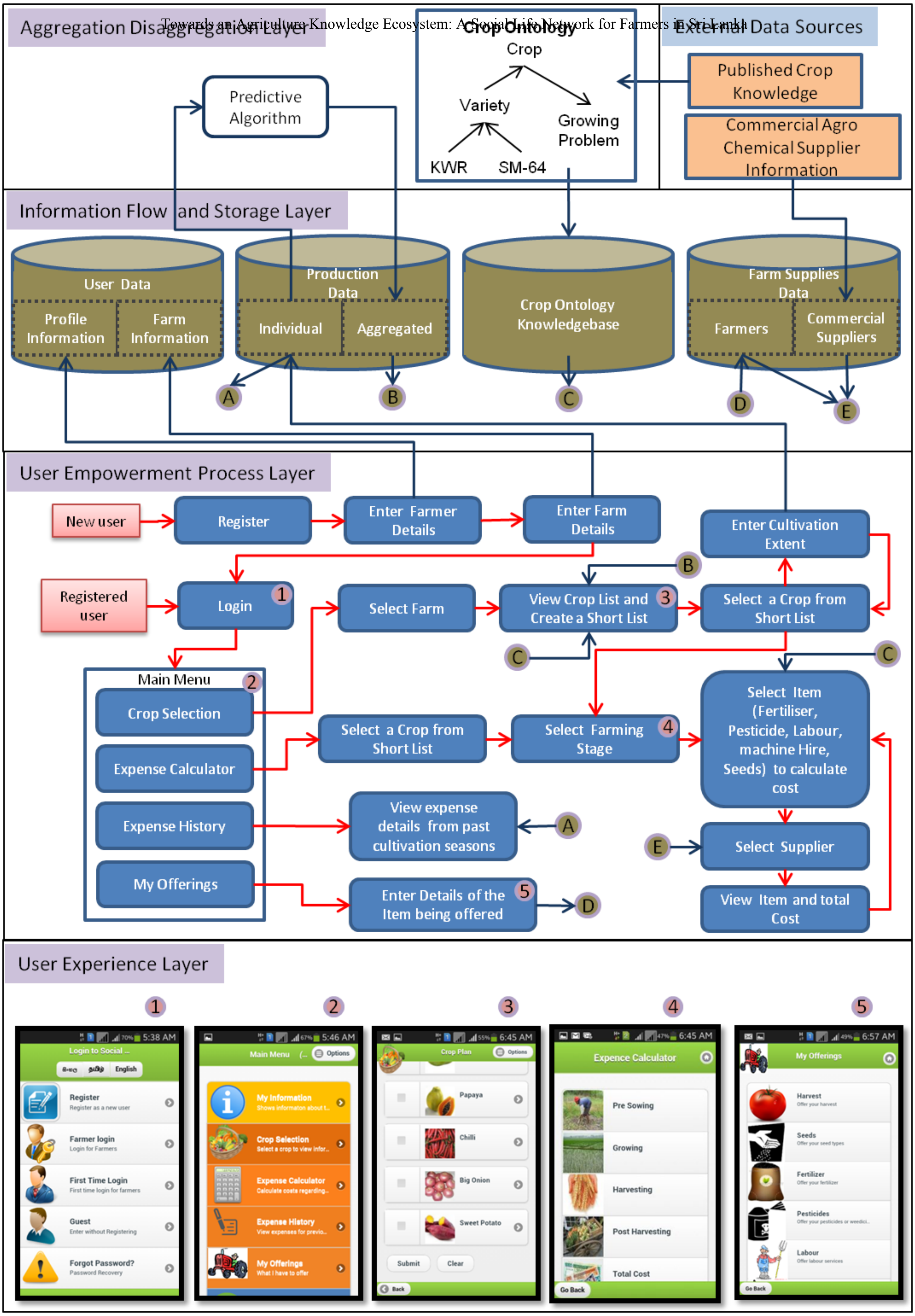

Fig. 5 High-Level Layered System Architecture and Functionality.

The *"User Empowerment Process Layer"* contains various processes for farmers to interact with the system. The new users can self-register with the system. The system sends their password via SMS. When registered users login to the system they are presented with the Main Menu. If they select "Crop Selection" they are then presented with a screen to select an already registered farm or they may register a new farm. Next, the system will present the list of crops that will grow in the selected farm and the option to view crop varieties and characteristics. The farmer can add selected crops to a shortlist and specify the extent of the planned cultivation. Once the extent of the planned cultivation is entered, farmer can navigate to the expense calculator in the Cultivation Planning Application. The other module in the Cultivation Planning Application is the expense history. In the Main Menu instead of Cultivation Planning Application these two modules are shown.

As shown in Fig. 5 the farmer can also enter the expense calculator directly from the Main Menu. The farmer first selects a crop from the short list to calculate the expenses associated with different stages of the farming life cycle. For each stage the farmer is provided with the relevant information on fertiliser, pesticides, chemical and seeds obtained from the crop knowledgebase and potential suppliers and the cost from the farm supplier database. From the main menu farmers can also go to "My Offering" module and enter products and services that they would like to offer. This information is made available to other farmers to purchase these products or services when they are calculating the expenses relating to their planned cultivation.

The "*User Experience Layer"* contains various user interfaces for the user to interact with the system. The new user interfaces were designed to enhance the usability by addressing issues observed during early field trials.

Towards an Agriculture Knowledge Ecosystem

Generalisation of the above system architecture and the behaviour, started to resemble a knowledge ecosystem. The knowledge ecosystem has been modelled based on Biological ecosystems (Briscoe 2010). Advances in Mobile Technologies have enabled us to create digital networks to enhance flow of information and knowledge and to create inter-dependent systems similar to biological ecosystems. In these systems information flows among stakeholders in place of energy flows in biological ecosystems (Briscoe 2010; Stanley and Briscoe 2010).

When developing systems that need access to both prior knowledge (static) and information generated in real time (dynamic), the digital knowledge ecosystem concept is very useful to conceptualise a potential solution. When dynamically generated information is needed, we need to identify the people who are producing this information and include them as part of the system. Often these people also need information produced by others to perform their activities. For example farmers need information about crops prepared by the Department of Agriculture. On the other hand the Department of Agriculture needs crops and extent planted by farmers to predict the supply of harvest coming to the market in the future months to ensure food security in the country.

Success of such systems relies heavily on stakeholders providing information required by others in a timely manner, which is a challenge. By combining information consumption and production through empowerment processes we can address this challenge. Thus development of various application modules should start by identifying stakeholder goals. Based on this information we can design the empowerment processes for each of the stakeholders.

Based on users' education, cognitive abilities, familiarity with similar systems, culture, language, etc. the user interfaces can be developed. This provides a useful way to partition the system into set of layers as shown in Fig. 6. Various modules in the application will make use of these layers creating a matrix structure shown in Fig. 7. This architecture provides a good basis to manage the complexity of such applications.

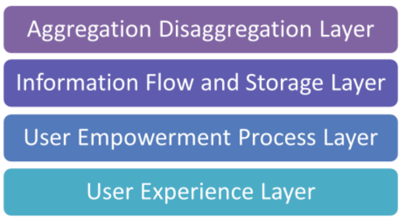

Fig. 6 Conceptual Architecture for Digital Knowledge Ecosystem.

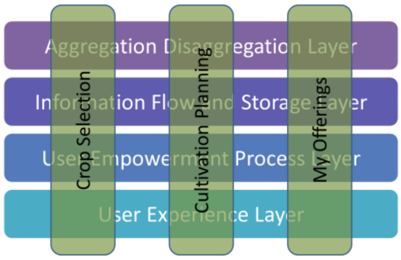

Fig. 7 SLN application modulesoverlaid on the Conceptual Architecture.

Conclusion

Through series of iterative cycles based on Design Science Research methodology we have developed and successfully trialled a Social Life Network (SLN); a novel mobile based information system for farmers in Sri Lanka. We discovered the interdependency among stakeholders to obtain the information that they need and reconceptualised our design as a Digital Knowledge Ecosystem for the agriculture domain. Already a few banks have approached us to investigate how micro financing can be linked to the system. Thus we believe over time the stakeholder base will grow.

Acknowledgments

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