CommonKADS Model Framework for Web Based Agricultural Decision Support System

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ABSTRACT

Increased demand of farm productions and depleting natural resources compelled the agriculture community to enhance the use of Information and Communication Technology (ICT) in various farming processes. Agricultural Decision Support System (DSS) proved useful in this regard as the agricultural systems are complex and partially known. The majority of available Agricultural DSSs are either crop or task specific. There are very less endeavors found in the direction of comprehensive DSS. The specific DSSs mainly developed with rule based or knowledge transfer based approach. These methodologies lack the ability to scale up and to support the development of large DSS. Modeling approaches are more suitable than so called transfer approaches for large and inclusive DSS. Unfortunately, it is found that that the model based knowledge engineering approach is not much utilized for the development of Agricultural DSS. The modeling approach to construct Knowledge Base Systems (KBS) becomes well accepted among the Knowledge Engineering (KE) communities due to its modular structure and ability to break down the knowledge engineering problem into smaller tasks. Modeling approach for the development of DSS offers the broad idea of structure and modules of the support system before hand. There are many modeling frameworks proposed and subsequently used by the KE communities. CommonKADS is one of the popular modeling frameworks for KBS. The paper presents the organization, agent, task, communication, knowledge and design models based on CommonKADS approach for development of scalable, broad and practically usable agricultural DSS. A web based DSS developed with multi agent CommonKADS modeling approach. The system offers decision support for irrigation scheduling and weather based disease forecasting for the popular crops of India. The proposed framework along with the required expert knowledge, provide necessary platform on which the larger DSS can built for any crop of given locations.

Keywords: Agricultural decision support system, CommonKADS, irrigation scheduling, disease forecasting, India

1. INTRODUCTION

Agriculture is as a complex and semi-structured system. Due to its complexity, it emerges as one of the potential subject areas of Decision Support System (DSS) (Eom & Kim, 2005). Increased demand of farm productivity and depleted natural resources made the Agricultural DSS very important interdisciplinary research topic in recent past. Agricultural DSS encompasses computer based solution to manage one or more spatial and temporal variability aspect associated with agricultural system. Its aim is to improve productivity and profitability of the agricultural system in spite of different variability (Pierce & Nowak, 1999), (Naiqian Zhang, 2002). It also helps to conserve the natural resources by their optimum usage. Use of DSS makes the overall agricultural system sustainable. In research publication such systems broadly categorized as Decision Support System (DSS), Expert System (ES), Knowledge based (or Intelligent) DSS, and Web based DSS (Manos, Ciani, Bournaris, Vassiliadon, & Papathanasious, 2004). Expert System aims to achieve better performance of specialized problem with an involvement of computer program. The computer program behaves like an expert person. Decision Support System helps to take decision with the help of available data (or information) and domain knowledge for unstructured and semi-structured problem (Ford, 1985). Although there is no specific depiction for IDSS and Web based DSS, one can interpret them as a hybrid system of DSS and ES. Role of these systems are diagnostic, advisory, informative and operational. Application areas of these systems encompass wide-ranging activities of agricultural such as irrigation scheduling, farm management, disease identification, disease forecasting and nutrition advisory (C.C. Shock, 2010), (Leib, Todd, & Gary, 2001), (Magarey, Borchert, Fowler M., Sutton, Colunga-Garcia, & Simpson, 2007), (Papadopoulos, Kalivas, & Hatzichristos, 2011). Better accessibility of internet among the farmer communities made it an obvious choice to focus on web based agricultural DSS. In the recent past, several research publications demonstrate growing interest in this type of decision support systems.

Field of Agricultural DSS is quite established and offers a wide variety of support system. Detailed discussion on various crop specific management systems like – EPIC (Maize and Cowpeas), Glycim (Soybean), FASSET (Wheat), AGDSSP (Sugarcane), HADSS (Wheat), etc. is well presented in (Antonopoulou, Karetsos, Maliappis, & Sideridis, 2010). Such type of DSS mainly offers decision support exclusively for the concerned crop. The climate forecast information system like 'AgClimate' provides the prior information about the weather to mitigate climate variability issue (Fraisse, et al., 2006). Large amount of process specific Agricultural DSS for irrigation scheduling, nutrition management and pest management found in the research literature (Leib, Todd, & Gary, 2001), (Alminana, L.F.Escudero, M.Landete, J.F.Monge, A.Rabasa, & J.Sanchez-Soriano, 2010), (Papadopoulos, Kalivas, & Hatzichristos, 2011), (C.C. Shock, 2010), (Magarey, Borchert, Fowler M., Sutton, Colunga-Garcia, & Simpson, 2007). It is found that the development approach considered in the majority of the Agricultural DSS is either rule based or knowledge transfer based. It is also found in the exhaustive survey on expert system that the model based knowledge engineering is not much popular in the development of Agricultural DSS (Liao, 2004). The core of knowledge modeling is to represent an expert system as implementation-independent model of competence. It represents the structure of the system prior to its implementation in a particular tool (Motta, 2001).

This paper presents CommonKADS modeling framework for web based Agricultural DSS. The paper provides the organization, agent, task, communication, knowledge and design models based on CommonKADS approach for development of scalable, broad and practically usable agricultural DSS. This provides a more general view on the Agricultural DSS problem. Hence, it is possible to develop comprehensive (not crop or task specific) decision support system on this modeling framework. Modeling approach offers the developer and the manager a broad idea of what the support system will look like and how they will implement the systems. The next section presents all the above mentioned models of CommonKADS modeling framework for Agricultural DSS.

2. COMMONKADS MODELING FRAMEWORK

The modeling approach to construct Knowledge Base Systems (KBS) becomes well accepted among the Knowledge Engineering (KE) communities due to its modular structure and ability to break down the knowledge engineering problem into smaller tasks. The models help to select and configure the reusable components for a specific application. There are many modeling frameworks proposed and subsequently used by the KE communities. These are CommonKADS, MIKE, PROTAGE-II, VITAL, Commet and EXPECT (Studer, Benjamins, & Fensel, 1998). The CommonKADS proposes six models in the construction process of KBS. The models are organization, agent, task, communication, knowledge and design (Schreiber, Wielinga, Hoog, Akkermans, & Veld, 1994). The proposed framework facilitates to develop generalized Agricultural DSS with ability to provide decision on optimum irrigation scheduling and weather based forecasting of diseases to the farmers. The subsequent part of the section proposes various models for Agricultural DSS in CommonKADS framework.

2.1 Organization Model

This model provides the organizational structure for the problem under the investigation. The important actors, their roles and major functions presented in this model. For the proposed Agricultural DSS, the major actors are knowledge provider (agricultural scientist, geologist and microbiologist), knowledge engineer/manager, knowledge system developer and knowledge user (farmers). Figure 1 shows the organization model of web based Agricultural DSS. The roles and functions of each actor are included in this model. The knowledge providers are traditional experts of the domain. The knowledge engineer elicits the domain knowledge from the knowledge providers. The knowledge acquisition and elicitation process are required to carry out with specific knowledge or expertise model. More details on this are provided latter in the respective section. Knowledge system developer employs the knowledge system using suitable software platform. Sometimes this role is played by the knowledge engineer also. Finally, the farmers are the end user of the knowledge. The final form of the knowledge must be in usable form and must be appealable to the user.

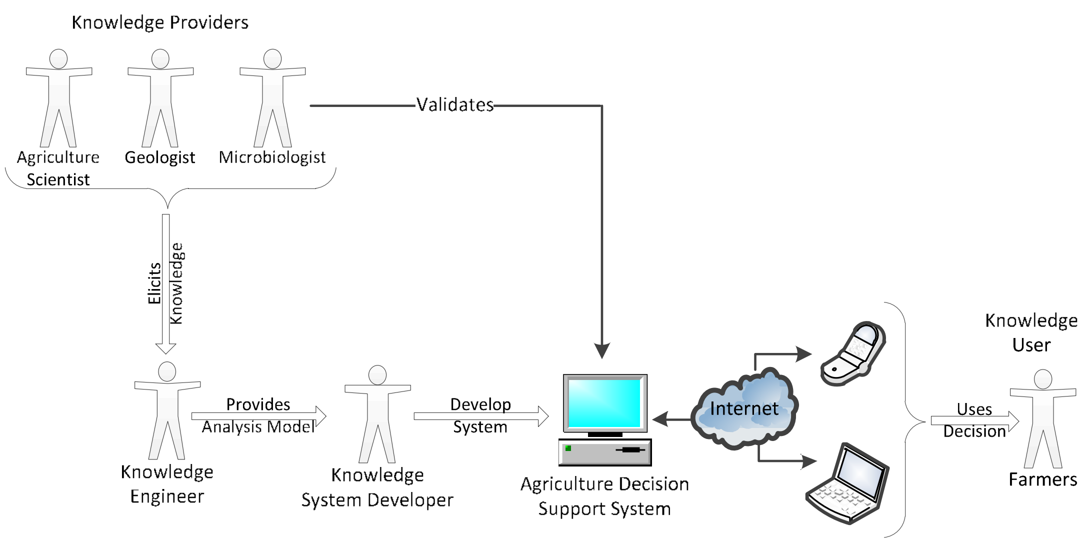


Figure 1. Organization model of web based agricultural decision support system

2.2 Task Model

In CommonKADS framework, the entire problem is converted in to different tasks. Each task represents separate function expected from the KBS. The task model demonstrates required inputs, information processing, knowledge precondition and expected output from each task. In general the task model offers an in depth task analysis for the processes identified. For the proposed agricultural DSS, two processes are considered. These are irrigation scheduling and disease forecasting. Combined task and agent model is presented in figure 2.

Three major approaches found in the literature for irrigation scheduling. These are soil moisture based, plant based, and weather based (A.A.Andales, Chávez, & Bauder, 2011), (Dukes & Scholberg, 2005), (Goldhamer & Fereres, 2004), (Sharon & Bravdo, 2000). Unlike to soil moisture based and plant based methods, weather based method does not require costly and specific sensors for the measurement of soil moisture, canopy temperature and leaf thickness. It is more realistic to use this method for irrigation scheduling. For this task the static inputs are type of soil, type of crop, development stages (for root zone information) and crop co-efficient values, K_c. It also needs dynamic data like – current value of temperature, wind velocity and humidity. Weather based disease forecasting is one of useful tool to protect the crop from the loss due to pest and diseases (Magarey, Borchert, Fowler M., Sutton, Colunga-Garcia, & Simpson, 2007), (Soon Sung Hong, Kim, Kim, & Kang, 2010) . The second task proposed is to suggest the farmers about the probability of occurring specific disease at the given point of time. This task needs the dynamic inputs as mentioned in the first task. Apart from this huge knowledge base of various pathogens and their favorable climate conditions are required to complete this task.

2.3 Agent Model

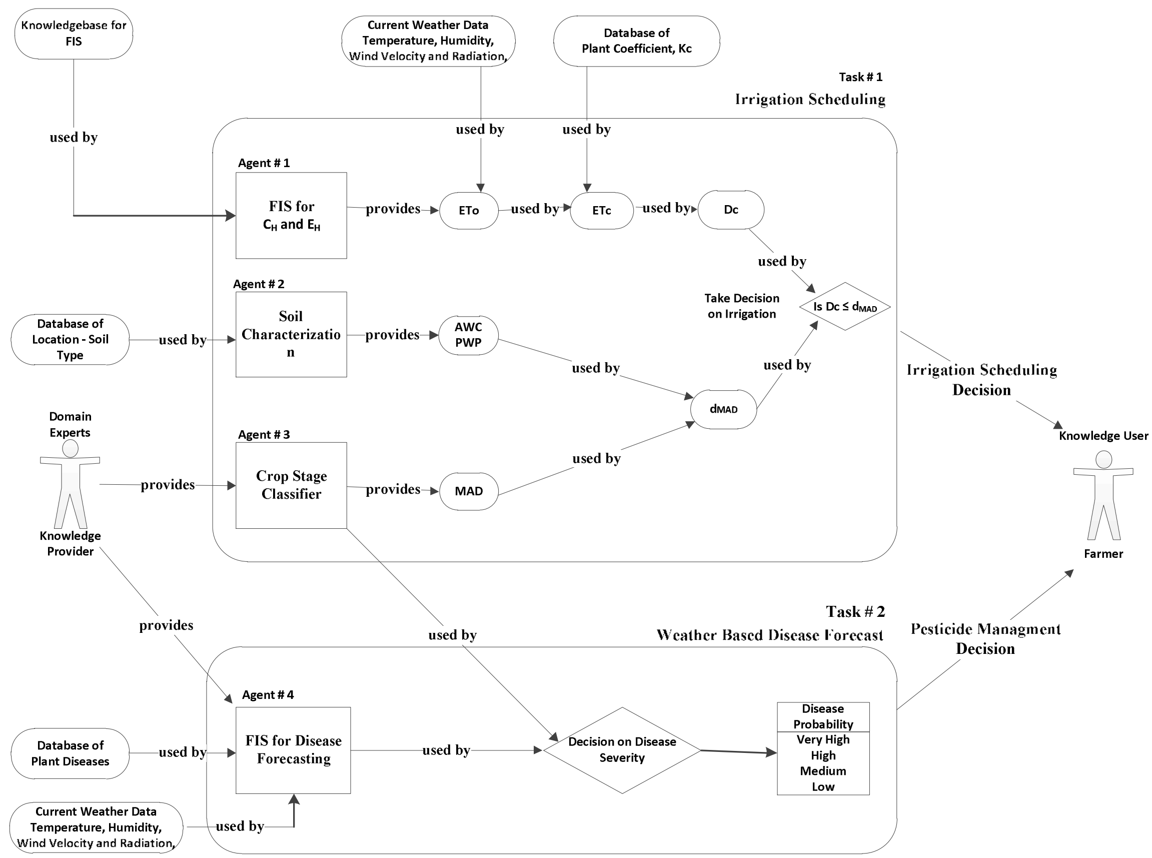
The task model demonstrate what need to done to achieve the task. An agent performs the task. Each task could be carried out by one or more agents. Here the agent word is used in the general sense. It could be human, computer program or some intelligent machine. As shown in fig. 2, the first task needs three agents and the second needs one agent. Accurate estimation of Evapotranspiration (ET_o) is very important for the implementation of weather based irrigation scheduling. Fuzzy Inference System (FIS) system is used for the adjustment of the Hargreaves equation (for accurate estimation of ET_o) parameter (Patel, Patel, & Bhatt, 2012). Agent # 1 provides these values. Soil characteristics like Available Water Content (AWP) and Permanent Wilting Point (PWP) are very significant for irrigation scheduling. Agent # 2 provides these data from the soil database, which is created from the knowledge of geologist. The third agent provides the information related to the crop stage and root zone depth. Agent # 4 inferences the probability of disease occurrence using the weather and crop stage data.

2.4 Communication Model

In a multi agent system, the communication between the agents is an important part. The communication model structures the dialogue between agents. It specifies the details of the information exchanges between the agents. In the proposed case, agent # 4 needs the data from agent #3 to complete the second task of disease forecasting. Similarly, the agents get the information from the database or the knowledgebase. In the proposed model agent #1 and agent #2 takes the information from the knowledgebase and database. The communication model presents the flow of information among the agents as well with the external information sources. It also covers the information exchange specifications like – provide, used by, elicits, requests, offers, etc., Figure 2 depicts the communication structure of the proposed DSS.

2.5 Knowledge Model

Knowledge model is an important aspect in CommonKADS framework. There are several advantages of knowledge acquisition to be carried out in modeling paradigm. In a conventional rule based KBS development there is a knowledge acquisition bottleneck. In this the development of the system is more depend on the expert.



AWC = Available Water Content in mm
PWP = Permanent Wilting Point in mm
C_H and E_H = Co-efficient for the Hargreaves equation for ET_0
K_c = Plant Co-efficient
ET_c = Plant Evapotranspiration in mm/day
MAD= Management Allowable Depletion in %
FIS = Fuzzy Inference System

Figure 2. Agent, task and communication model of agricultural decision support system

The main difficulties of rule based approach are knowledge elicitation from the experts and convert them into the system. A knowledge model provides a knowledge-centric view. It specifies the type of knowledge required to complete the task. This model used as knowledge elicitation tool for the knowledge engineer. Careful design of the knowledge model speed up the process of knowledge acquisition. It is an important approach to create more general KBC. To implement an irrigation scheduling task, several details about the crop and soil are required. These can be collected from the concern domain experts in the form shown in Table 1. The design of knowledge model is to prepare the details of expected information from the experts. Disease forecasting task needs the knowledge from the microbiologist and agriculture scientist. The proposed knowledge elicitation form for this is shown in Table 2.

Table 1. Knowledge elicitation form for irrigation scheduling of cotton crop

Crop Name	**:** Cotton (Gossypium)		
Variety	: H8, H10		
Preferred Month of Sowing	: July - August		
Best Suitable Type of Soil	: Black		
Suitable pH level	: 6 to 7.5		
Plant Days	: 160 to 180		
Stages	**Number of Days**	**Root Zone Depth, cms**	**Plant Coefficient, Kc**
Initial	: 0 to 45	: 10	: 0.35
Development	:46 to 85	: 11 to 25	: 0.35-1.20
Mid Season	: 86 to 110	: 26 to 40	: 1.20
Late Season	:111 and above	: 40	: 1.20-0.5
Stages	**Best Temperature Range °C (Day Temp)**	**Best Humidity %RH**	**% Management Allowable Depletion (MAD)**
Initial	: 28 to 30	: Any percentage	: 55
Development	: 30-32	: < 60 %	: 55
Mid Season	: 30-35	: < 25 %	: 65
Late Season	: 35-38	: < 17 %	: 75

Table 2. Knowledge elicitation form for disease forecasting of corn crop

Pathogen and Disease	**Susceptible Stage**	**Days after sowing**	**Maximum Safe Day Temp °C**	**Minimum Safe Day Temp °C**	**Maximum Humidity %RH**	**Leaf Wetness Duration Hrs**
Pathogen Fungus *Puccinia Sorghi* (Common rust)	Development Stage	45 to 80 Days	25-28	10-12	80-90	6 Hrs

2.6 Design Model

This model suggests the tools to covert the concept into the implementation. It specifies hardware and software platform. The details about the functional and technical specifications of various modules are provided in this model. In the proposed case, the preferred open source platforms like Android and Java are selected for the implementation of web based solutions. To improve the accessibility of the DSS among the farmer community, use of mobile device is planned out. The design model consists of the relevant information about the KBS.

3. DISCUSSION

Agricultural system is quite complex and partly known. Design of decision support system for the agricultural system is quite challenging and involved. CommonKADS model approach provides modular and scalable framework. The model approach needed to construct multi tasking and general (non specific to crop) DSS. The entire problem can be break down into the smaller part designated as various models like - organization, agent, task, communication, knowledge and design models. The advantage of model approach is that one can look at a particular model at a time and analyses accordingly. The organization model provides an overview of the problem and role of various actors in the DSS. The strategy for the task is presented with required details in the task and agent model. Knowledge model includes the knowledge elicitation form for the crop and disease details. A complexity level of the forms is kept such that they serve the purpose without creating any unnecessary hassles to the knowledge providers. Careful designing of the knowledge model ensure the streamline flow of knowledge to the system. The hardware and software requirement defined under the design model.

4. CONCLUSION

Development of a web based Agricultural DSS is presented in well known CommonKADS modeling framework. It is always advantageous to undertake the DSS problem with model approach. It helps to remove the bottleneck of knowledge acquisition occur in so called knowledge transfer approach. Typically, in Agricultural DSS development knowledge modeling approach encourage the reuse of knowledge. In a present scenario, the Agricultural DSSs are either crop or task specific. These limitations are emerged as these systems are based on convention rule based or knowledge transfer approach. More and more use of model based approach in the development of Agricultural DSS certainly pushes the development in more general and comprehensive pattern. It has an edge over the conventional knowledge transfer approach in terms of scalability and modularity.

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