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KrishiSENSE: Web and Mobile based Agriculture DSS

Agriculture Decision Support System is possible to implement with two different framework. The first one is to use actual sensors for the measurement of the required field parameters like temperature, humidity, soil moisture, canopy temperature, etc. Successful use of Wireless Sensor Network (WSN) for the integration of the measurement is presented by many researchers (Matese, et al. 2009), (Panchard, et. al, 2010), (Vellidis, et. al 2008). Agriculture DSS with the WSN has advantage of precise measurement of field related variable. But, this option is very costly as it involves sensor nodes. With reference to Indian agriculture condition, this is not a viable solution. The second approach is to acquire the required field variables through the web based public services. In case of irrigation scheduling such variables are temperature, relative humidity and wind velocity. These are easily available through paid as well free public services on internet. This will eliminate the need of sensors or any other components of electronics.

There are several advantages of web based DSS like integration of multidisciplinary knowledge, client-server based model and centralized knowledge base compare to traditional standalone computer aided tool (Zhang & Goddard, 2007). The web based agriculture DSS, KrishiSENSE (www.krishisense.org) is developed with a focus on irrigation scheduling. The first section of the chapter presents the overall structure of the system. General outline of the irrigation scheduling algorithm is also discussed. The next section provides detailed software system diagrams and case studies of the web based DSS. For the common farmer, it is not possible to get the access of
computer and internet connectivity. So, usability of web based DSS is challenging. Fortunately, the availability of mobile service coverage is quite satisfactory in India. Further, the availability of low cost smart devices and mobile data networks (2G and 3G) played the game changer role in the rural parts of the country. Today, there is hardly any geographic area of the country left without mobile network. To harness this facility, mobile application of KrishiSENSE is also developed on Android platform. This dynamic application is connected through the same server to achieve seamless integration of web and mobile application. The last section of the chapter presents the software system diagrams as well case studies of the mobile application.

6.1 Overview

It is important to understand the overall organization structure of the system before enter into its nitty-gritty. The current section unveils the concept model and basic algorithm of irrigation scheduling used in the KrishiSENSE.

6.1.1 Concept Model

The KrishiSENSE web application is developed using Java based technologies. The web application is deployed on Apache Tomcat Web server (open source). The open source IDE (eclipse) has been used to develop the KrishiSENSE web application. The innovation is to use the free public web service for collecting weather related data required to execute the algorithm for irrigation scheduling. This provides irrigation related information to the farmers. The MySQL database (free downloaded database) is used for maintaining the data related to the system. Mobile application of KrishiSENSE is developed on free Android platform. It supports the Android version 4.0 and higher. An additional feature of the mobile application is that it provides current rate of commodities in the wholesale market APMC (Agricultural Produce
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Market Committee) of the different towns and cities. The overall concept diagram is presented in the figure 6.1.

Figure 6.1 Concept diagram of KrishiSENSE

6.1.2 Irrigation Scheduling Algorithm

As discussed in the section 2.3 the irrigation scheduling systems are classified into three major types: soil based, plant based, and weather based water balance. The weather based water balance is the suitable method for the web based irrigation scheduling methods. As, in this method the irrigation scheduling is decided on the basis of balance of water available in the field. The algorithm of the expert system is based on the paper presented under the agriculture extension work (Andales, Chávez, & Bauder, 2011). The main principle of the water balance is shown in equation 6.1.

\[ D_c = D_p + ET_c - P - I_{irr} - U - SRO + DP \]  

(Equation 6.1)
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Where,

\[ D_c = \text{Current day deficit in mm} \]
\[ D_p = \text{Previous day deficit in mm} \]
\[ ET_c = \text{Evapotranspiration rate in mm/day} \]
\[ P = \text{Precipitation or Rain in mm} \]
\[ Irr = \text{Net irrigation amount for the current day in mm} \]
\[ U = \text{Upflux of ground water into root zone in mm} \]
\[ SRO = \text{Surface runoff in mm} \]
\[ DP = \text{Deep percolation or drainage in mm} \]

The water balance equation (Equation 6.1) confirms that the available water in the field is decided by the evapotranspiration rate, irrigation, upflux of ground water, surface runoff and deep percolation. If we consider the controlled irrigation for the field crops (not the large tree) the last three factors (i.e. upflux of ground water \((U)\), surface runoff \((SRO)\) and deep percolation \((DP)\)) can be considered as zero and removed from the equation.

Due to evapotranspiration, soil moisture continuously depletes. On other hand soil particles attract water due to chemical bonding and texture. Once the soil moisture deplete to an extreme level, plant will not able to take further water from soil. This point is known as Permanent Wilting Point \((PWP)\). At this point, the plant undergoes water stress and productivity of plant hampers. It is not advisable to allow soil moisture to reach up to PWP. Management Allowed Depletion \((MAD)\) is a point up to which plant does not undergo water stress. Decision for irrigation is required to be taken in the comparison of daily MAD i.e. \(d(MAD)\) with current deficit of water in the field. \(d(MAD)\) is depends on Available Water Capacity \((AWC)\) and the current root zone of the crop. This relation is shown in equ. 6.2. More details are available in (Patel, Patel, & Bhatt, 2012).
\[ d_{MAD} = \frac{MAD}{100} \times (AWC) \times D_{rz} \]  

(Equation 6.2)

Where,

\( d_{MAD} \) = Daily management allowed depletion in (mm)

\( MAD \) = Management allowed depletion in (%)

\( AWC \) = Available water capacity in (mm of water /mm of soil)

\( D_{rz} \) = Root zone of crop in (mm)

Root zone of crop \( D_{rz} \) varies according to crop growth stages. When the field reach to the condition where the water deficit for current day \( (D_c) \) become higher than the daily management allowed depletion \( (d_{MAD}) \), the irrigation for the field required to arrange. The equation is presented in equation 6.3.

\[ D_c \geq d_{MAD} \]  

(Equation 6.3)

The factors affecting the irrigation schedule for water balance in the field are as follows:

1. Current and past weather parameter values - temperature, relative humidity, wind velocity and solar radiation

2. Evapotranspiration rate \( (ET_0) \)

3. Available Water Capacity \( (AWC) \) of soil

4. Management Allowable Depletion \( (MAD) \) of the concern crop at particular stage.

5. Crop co-efficient \( (K_c) \)

It has been evident from the above discussion that several data regarding crop, field and weather are static in nature and the rest are dynamic. The static data are \( AWC \) of soil, stage wise \( MAD \) of the crop, stage wise root zone depth \( (D_{rz}) \) and plant co-efficient \( (K_c) \). These data are required to provide once in the software system. Data considered in the development of the systems are provided in Appendix A. The dynamic data are temperature, relative humidity and wind velocity.
of a particular field. These data are collected through the open public service on internet. These data are updated once in a hour. Reference evapotranspiration rate \( (ET_0) \) is important term for the calculation of current day deficit \( (D_c) \). (Please refer equation 6.1). The Hargreaves equation (equation 6.4) is used to estimate \( ET_0 \) from the current weather conditions.

\[
ET_0 = C_H (T_{\text{max}} - T_{\text{min}})^{E_H} (T_{\text{mean}} + 17.8)R_a \quad \text{(Equation 6.4)}
\]

The Hargreaves equation is not consistent for the extreme weather conditions (D.T.Jensen, et. al 1997), (Amatya, Skaggs, & Gregory, 1995). In the present work an accuracy of the Hargreaves equation is improved by using the calibrated value of constant \( C_H \) and \( E_H \) using fuzzy logic based calibration method (Patel, Patel, & Bhatt, 2014). Calibrated value of constant \( C_H \) and \( E_H \) considered for the locations are provided in Appendix B. Evapotranspiration rate \( (ET_c) \) is calculated using Reference evapotranspiration rate \( (ET_0) \) using following equation 6.5.

\[
ET_c = K_c \times ET_0 \quad \text{(Equation 6.5)}
\]

At present, the expert system for irrigation scheduling is equipped with the knowledge base for the eight prominent crops of the Gujarat states. These are cotton, groundnut, castor, wheat, maize, rice, mustard and bajara. The most popular varieties of these crops are considered to develop the knowledge base. The user can enroll only those crops whose knowledge base is incorporated in the system. The crop details like – total and stage wise plant days, stage wise rootzone depth, stage wise plant coefficent \( (K_c) \), stage wise % Management Allowable Depletion \( (MAD) \), etc., are required to collect from the domain experts. Required information is collected through series of interviews with the expert. Format of the data collection form is provided in Appendix C.
6.2 KrishiSENSE: Web Application

An expert system for the irrigation scheduling is developed on the web-client platform. To avoid the problem of licensing, it is developed on the open platform of JAVA and MySQL database. In true sense the proposed web application is open to use. The web application is deployed on Apache tomcat web server (open source). The open source IDE - eclipse is used to develop the KrishiSENSE web application. The innovation is use of free public web service for acquiring weather related data required by KrishiSENSE. The working model is proposed such a way that it can be offered to the farmers free of cost. The subsequent parts of the section provide more insight of the system analysis and design. At the end of the section case study is being provided for the better understanding of the system.

6.2.1 Introduction and Profile

Web based agriculture decision support system, it is hoisted at www.krishisense.org. It is based on client-server technology. The server keeps all the data pertaining to the crop, filed and user data. At present it is ready for most popular eight crop of the Gujarat and twenty seven locations of the state. It is developed such a way that it can be expand very easily and made it for the entire country. The system architecture is presented in figure 6.2.

6.2.2 Navigation Detail

There are three navigation paths in the KrishiSENSE: (1) visitor (2) farmer and (3) admin. It provides bird view on the overall portal. The details are given in subsequent section.

(1) Visitor page

This is the home page for the portal. It comprises of tabs for home, login, download, feedback and about us. Access at this page is possible without login credential by the user. The details are given in figure 6.3.
(2) Farmer page

This page is only accessed by the registered users of the system. After getting the login in the page, the farmer is able to add farm in his list. He can also see the list of already existing farm under his login. He can also generate the consolidate reports on his farm. The navigation details are provided in figure 6.4
(3) Admin page

The access of this page is only for administrator. It has navigations for home, farm list, add crop, view crop and report. Farm list displays the total farms registered by the farmers. Through add crop, admin can add knowledge base of the new crop. The farmer can only add those crop whose knowledge base is available with the system. Using view crop tab, the admin of the system can view and edit the existing crop details (please refer appendix A). The refinement of the knowledge is easily possible with this feature. The navigation details are provided in figure 6.5.
6.2.3 System Analysis and Design

Various UML diagrams are presented in this section to clarify the internal architecture and design flow of the application development.

System Flow Diagram

System flow diagram shows the overall interaction of farmer with the system starting from the registration to irrigation scheduling. It is shown in figure 6.6

Use case Diagram

Use case diagram is useful to demonstrate various functions of the system in the form of Use-cases with the users who play the role within the system in the form of actors. It describes a set of actions which system should perform in collaboration with one or more external users of the system known as actors to provide some observable and valuable results to the actors or other stakeholders of the system. Use case diagram of the mobile application is presented in figure 6.7

Class Diagram

Class Diagram is a static view of a system. It shows the structure of the designed system, subsystem or component as related classes and interfaces. It demonstrates features, constraints, relationships, associations and dependencies of the classes. It is presented in figure 6.8.

Activity diagrams

Activity diagrams are used to show the sequence and conditions for coordinating the detailed lower-level behavior. This diagram provides the information flow within the system. It shows sequence and conditions for coordinating the behaviors. KrishiSENSE web application has three major activities as follows:

(1) Farm Management (2) View Farm (3) Crop Management

The activity diagrams are presented in figure 6.9, 6.10 and 6.11.
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Figure 6.6 System flow diagram-web applications

Figure 6.7 Use case diagram- farmer login: web application
Figure 6.8 Class diagram - web application

Figure 6.9 Activity diagram – Farm management
Figure 6.10 Activity diagram – View farm

Figure 6.11 Activity diagram – Crop management
6.2.4 Functionality Check

The purpose of the section is to provide acquaintance with the web application with the help of a case study. So, the treatment of the section is kept just like as manual. Necessary snap-shots are added for easy understanding. The section describes the step-by-step functionality of the application. Here, the descriptions are made in context with the users.

Visitor page

General visitor, without login credential can view the content of the page. About us provides the objective of the portal to the visitor. Through the feedback page the visitor/user can share the feedback with the developer. In the download section there are three navigations available. The visitor can go through the important reference material used in the development of the portal. He can also see the publication related to KrishiSENSE. Under the software section, one can download the mobile application of the KrishiSENSE and the executable file of the fuzzy logic based Hargreaves equation calibration software – ECALTOOL. Through the login tab, the user can create the login or provide the login name and password to enter as the farmer in the portal. The care has been taken to keep the simplest possible details requirement for the login creation. The snap shot of the home page is provided in figure 6.12. The reader is requested to visit the page to have more familiarity with all the functions.

Farmer Page

Once the visitor has created the login or already the registered user, he can enter to this page. This page consists of the prime functionality of the portal. The figure 6.13 shows the typical farmer page. The page show the registered farmer name (Jignesh) and current date (06-09-2014). There are two possibilities at this level – (i) the farmer wish to add new farm or (ii) the farmer
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Figure 6.12 Visitor home page

Figure 6.13 Farmer page
wish to view the existing farm/s. The farm list selection provides the list of farms already available for the concern farmer’s login. Figure 6.13 displays the farm list of the farmer. This consists of already added field (or farm) under the same login. Add farm is important functionality. Here the farmer can add his new farm in the system. The farmer can add only those crops which are available in the knowledge base of the system. Add new farm form asking very simple details like – type of crop (selection from the drop down menu), variety of crop (selection from drop down menu), nearest place (selection from drop down menu), farm name and date of sowing. Farmer can add the farm with back date sowing. Once the farm is added successfully, it is available under the farm list.

The second functionality is the view farm. In this panel, farmer can get the details about the crop, soil, current prevailing weather and irrigation scheduling. Through this panel he can get the decision support regarding farm management. Figure 6.16 and Figure 6.17 shows the current weather and irrigation scheduling output respectively. The selected farm is the cotton farm located at Ahmedabad. The current weather panel displays temperature (26°C), relative humidity (91%), maximum temperature (32°C), minimum temperature (25°C), wind velocity (13 km/hr) reference evapotranspiration rate, $ET_0$ (3.82) and evapotranspiration rate, $ET_c$ (1.91) as on 6-09-2014 at 6.15 pm. These are very important information and it helps the farmer to manage the farming activity in general. Irrigation scheduling pertaining to the farm is display as a part of the panel. In the concern farm it is showing the dates – 20/08/2014, 09/09/2014, 28/09/2014, 10/10/2014, 03/11/2014, 28/11/2014 and 04/01/2015. Apart from irrigation scheduling and current weather information the system provides soil and crop related details. These are name of crop, important dates like emergence, flowering and maturity dates of the crop, type of soil, AWC of soil and MAD at the particular stage.
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Figure 6.14 List of farms of the concerned login

Figure 6.15 Add farm page
Figure 6.16 Current weather data from view farm page

Figure 6.17 Irrigation scheduling date for cotton crop at Ahmedabad
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Admin Page

As discussed in the earlier part of the section, the admin page is related to system administration functionality and adding and editing the required knowledge base of the system. Administrator can view the list of registered farmers and the total farms added under these farmers using view farm tab available in the page. This is useful as system management tool. He can delete or deactivate the any farm from this function. Important role of the administrator is to add and edit the knowledgebase of the crops. As mentioned in the farmer page description, the farmer can only add that crop whose knowledge base is available with the system. With add crop function, the admin can add new crop details in the system. The form is shown in figure 6.18. The knowledge elicited regarding various crops from the domain experts is entered at this page. Futher, all ready entered details can edit using view crop function.

![Figure 6.18 Add crop form under admin page](image)

Figure 6.18 Add crop form under admin page
6.2.5 Discussion

The smallest details of the system as flow of functions, performance of a each operation, execution of each module are thoroughly tested. With the help of volunteers the beta testing of the application is successfully completed. The web application is scalable and easily upgradable for more number of crops as varieties of the crop. More location can append in the system by adding geographical details correspond to the location of interest. Provision of future expansion for crisis management is also made. Apart from prime objective of the application- irrigation scheduling it also provides very useful information such as commodity prices, soil and crop details as well the current weather condition.

6.3 KrishiSENSE: Mobile Application

Mobile application - KrishiSENSE is a decision support system which helps the registered farmer to remotely know the current weather condition of his farm and also guide the farmer to arrange the irrigation schedule as per the scientific method. It also provides the commodity prices of the nearby market. The guided irrigation scheduling process helps to reduce the wastage of the water resources as well increase the productivity. The system is an Android Mobile App which can be easily installed on the any low cost smart devices like mobile or PDA. The application is highly flexible in the sense that it is compatible with all the latest versions of android as well as the previous versions of the android family. At present the system is built for the farmers of Gujarat state only. The mobile application can be easily upgradable for the entire country by adding the required soil and crop details in the admin module of the system. The subsequent sections present the system analysis and design along with the case studies and discussion on the result.
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6.3.1 Introduction and Profile

Just like most of the Android based mobile applications, KrishiSENSE is also free to download. It is available at the download section of www.krishisense.org. Being a dynamic application, to establish the connection with the server the user’s device must be connected to the internet. This connection is very much feasible with wide penetration of 2G and 3G data connection network through mobile services. Further, the application is supported by wide range of Android versions. So, there is no specificity of the smart devices. Over all system architecture is presented in figure 6.19

![Figure 6.19 Mobile Application – System Architecture](image)

6.3.2 System Analysis and Design

Various UML diagrams are presented in this section to clarify the internal architecture and design flow of the application development. Use case diagram of the mobile application is presented in figure 6.3 and class diagram is presented in figure 6.20.
Activity diagrams are used to show the sequence and conditions for coordinating the detailed lower-level behavior. This diagram provides the information flow within the system. It shows sequence and conditions for coordinating the behaviors. KrishiSENSE mobile application has four major activities as follows:

1. Sign up and Sign in Activity

This activity let the farmers to be active into the system by registering himself into the system and if he is already registered then it let him to sign into the system. The activity diagram is presented in figure 6.21

2. Farm Management Activity

This activity allows the farmers to manage his list of farms and facilitate him to perform certain actions on selected farm which includes add farm, delete farm, and activate/deactivate farm. The activity diagram is presented in figure 6.22
3. View Farm Activity

This activity allows the farmers to view detailed information about selected farm. The information comprises of four sections namely, current weather information, crop and soil information, irrigation schedule and crisis management. The activity diagram is presented in figure 6.23

4. Commodity Market Activity

The activity provides the farmers to fetch the latest commodity market price of various APMC (Agriculture Produce Market Committee). To get market price, the farmer needs to provide few details like commodity, date and APMC. The activity diagram is presented in figure 6.24

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![Diagram](image.png)

Figure 6.21 Sign up and sign in activity diagram

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Figure 6.22 Farm management activity diagram

Figure 6.23 View farm activity diagram
State chart diagram

State chart diagram shows various states through which the farmer goes as he interacts with the system. In another words it shows the flow of information within the system. The rectangular shapes represent the states and the arrows show the interaction between various states. The state chart diagram is presented in figure 6.25

6.3.3 Functionality Check

The purpose of the section is to provide acquaintance with the mobile application with the help of a case study. So, the treatment of the section is kept just like as manual. Necessary snap-shots are added for easy understanding. The section describes the step-by-step functionality of the application. Here, the descriptions are made in context with the users.
1. Menu Screen

At the successful downloading of the application of mobile devices, the user need to open the application. The opening screen and user dashboard are shown in figure 6.26. The user dashboard consists of various tabs to further navigate. These are login, commodity price, contact us, about us and feedback. Even without login authentication, the user can explore all the four paths. The dashboard is shown in figure 6.26.

2. Sign in, Sign up and Forgot Password

Already signed up user can enter through login panel. The new user can sign up with the minimum personal information like name and mobile number only. Sign in, sign up and forgot password panels are shown in figure 6.27
3. Registered farmer dashboard

After successfully registration with the application, the farmer is now able to access the personal dashboard. This screen consists of farm management and report navigation. Further, accessing the farm management, the farmer get two options – add farm and view farm functionality. View farm enables the farmer to view his existing farms with the system. Here, one –to- many relationship considered for farmer and farms. It is possible to have more than one farm with one farmer. The concerned snap shots are presented in figure 6.27
In the present case the farmer has already enrolled his farms at the location of Ahmedabad, Vadodara, Bhavnagar, etc., as shown in the snapshot.

4. View Farm Functionality

Once the particular is being selected, a new dashboard related to the concern farm is available. This consists of four tabs: current weather, crop and soil information, irrigation scheduling and crisis management. Current weather shows the latest temperature in degree Celsius, minimum and maximum temperature of the day in degree Celsius, relative humidity in %, wind velocity in km/hr, reference evapotranspiration (ET₀) and evapotranspiration (ETₜ). These are the most significant and important information for the farmers. Even the farmers can take many decision and action on the basis of this information. The second tab of the dashboard shows the crop and soil details. These are name of crop, important dates like emergence, flowering and maturity dates of the crop, type of soil, AWC of soil and MAD at the particular stage. The third tab is about irrigation scheduling. It shows the expected date of the irrigation for the given crop. For example, the cotton crop of in the field nearby Dahod has
the irrigation date as – 18th August, 5th and 9th September and 5th and 14th October. This date is calculated using the algorithm discussed in the section 6.1.2. The screen shots are given in figure 6.29.

![Figure 6.29 View farm functionality](image)

Provision for the crisis management is made in the system but not included at present. This will be corrective suggestion to the farmers regarding pest management as well other corrective steps to protect the crop. This may be taken as future work.

### 6.3.4 Discussion

The minute details of the system such from functioning of a button to the execution of a module are thoroughly tested. With the help of volunteers the beta testing of the application is successfully completed. The design of the application is made such a way that the future expansion of crisis management can easily incorporate. Apart from prime objective of the application- irrigation scheduling it also provides very useful information such as commodity prices, soil and crop details as well the current weather condition. Mobile version of KrishiSENSE is going to be boon to the farmers.