AN ANDROID-ARDUINO SYSTEM TO ASSIST FARMERS IN AGRICULTURAL OPERATIONS

ARPIT NARECHANIA

BTech 4th year Mechanical Engineering, IIT Mandi
E-mail: arpitnarechania@gmail.com

Abstract—Agriculture accounts for ~15% of the Gross Domestic Product (GDP) of India but employs close to 50% of the working population. Average yield in India is quite low compared to other countries. Advances in Information and Communication Technology (ICT) and the government initiatives in e-governance are only promoting e-agriculture in India. This can not only improve the condition of Indian agriculture but also the life and working conditions of the farmers. This paper is about an android application, using ICT, promoting e-governance by providing continuous information pertaining to agriculture like weather forecast, crop prices, news, government helplines, and an inventory database manager. The mobile application also connects to 1) an Arduino based mobile robot to perform field operations like ploughing, seed sowing over Bluetooth channel 2) an Arduino based system fixed in the field comprising a wireless sensor network (WSN) of soil moisture, pH and temperature sensors for data acquisition and remote control of water pumps for watering and irrigation over the Global System for Mobile communication (GSM) and Bluetooth networks.

Index Terms— e-agriculture, arduino-android robot, wireless sensor networks, ICT

I. INTRODUCTION

Agriculture, "The backbone of Indian economy" (MK Gandhi), defined as an integrated system of techniques to control the growth and harvesting of animal and vegetables. It is an uncomplicated endeavor comprising of technical and practical processes that helps in the maintenance of the ecological balance and protects human resources; most importantly it is a viable food production system [5]. In 2012-13 agriculture contributed to 13.9% of the total GDP [8], and employed 47% of the total workforce population [32]. The combined efforts of Central Government, State Governments and the farming community have succeeded in achieving a record production of 264 MT of food grains during 2013-14 [12],[10]. This record production has been achieved through effective transfer of latest crop production technologies to farmers under various crop development schemes being implemented by the Department of Agriculture & Cooperation backed by remunerative prices for various crops through enhanced minimum support prices. As Indian economy has diversified and grown, agriculture's contribution to GDP has steadily declined from 1951 to 2014 [8], yet it is still the largest employment source and a significant piece of the overall socio-economic development of India. Crop yield per unit area of all crops have grown since 1950, due to the special emphasis placed on agriculture in the five-year plans and steady improvements in irrigation, technology, application of modern agricultural practices and provision of agricultural credit and subsidies since the Green Revolution in India. However, international comparisons reveal the average yield in India is generally 30% to 50% of the highest average yield in the world [11].

In 2010, there were 38 crore mobile telephones in rural areas, 9 crore farm households and Internet penetration is currently at 5% but improving [22]. This increasing penetration of mobile networks in India therefore presents an opportunity to make useful information more widely available. According to Barton (2003, cited by Abdullah 2013), websites provide farmers with the facilities to communicate with other farmers, extension officers and agencies across long distances. In addition, websites are the most popular online services for farmers, and are cheaper than telephone usage. Farmers are able to access information through ICT at any time, and this enables them to create networks with development agencies and other farmers, and eventually increase their chances to double their agriculture productivity according to Obiechina (2004, cited by Abdullah 2013) [2]. According to Pickerrnell et al. (2004, cited by Abdullah 2013) [2], ICT has certainly had a big impact on agriculture. It provides opportunities for farmers to expand their market and reach new customers through the Internet. One example that shows the successful use of ICT in agriculture is "mobile telephony". This has been used to access information on market price, weather and many other aspects. These changes provide advantage to farmers and offer them opportunities in terms of improving their quality of life. This could help agricultural markets operate more efficiently, and overcome some of the hurdles faced by it.

Mobile or smart phones are becoming an essential device for all types of users irrespective of the age group. High resolution cameras, high definition video with huge amount of memory; internet browsing through your handset and 3G and Wireless LAN connectivity; hardware like GPS, accelerometers, gyroscopes, Bluetooth are common to find on smart phones these days. Android the open-source mobile operating system developed by Google, is quickly becoming the smart phone operating system choice for all. As of June'14 there were 57,380,000+ Google Android and 4,854,000+ Apple iOS users in India [29]. The Application Programming Interfaces (APIs) and data directly from government servers can be used by developers to exploit these features for better services [24].

The Ministry of Agriculture, Govt. of India, has started various schemes in the interests of the farmers. The mKisan Portal inaugurated in July'13 by Honorable President of India has received as of 1,85,40,07,285 messages, 5,74,40,63,746 and 237,777 advises as of 8th April'15 [22].

The weekly/ daily stock availability with dealers of seeds and fertilizers was made available at Rs. 5/month/dealer [22].

USSD (Unstructured Supplementary Service Data), IVRS (Interactive Voice Response System) and Pull SMS provide broadcast messages – to get web based services on mobile without internet, in their language and voice messages for the illiterate [22]. Applications like Krishi Ville [35], Kissan Kerala [36] are an attempt to provide such information to farmers over internet.

In a recent analysis of data available on the e-governance dashboard, e-taal (Electronic transaction Aggregate and Analysis Layer), rural India has led a record 35% surge in use of e-governance with the states of Gujarat and Telangana coming on top. Of the 3.5 billion electronic transactions reported in 2014, 50% of them were from rural areas, which were responsible for only 20% of e-transactions the previous year (Patil, 2015) [25].

Based on NSS (National Sample Survey Organization) 59th Round Survey [25], the information regarding seeds was the most inquired information followed by the mandi (market) prices by the farmers.

Based on the survey, the most important requirements of the farmers were divided into 3 broad categories -know-how about seed varieties to use; contextual information for weather, local soil conditions; and market information about commodity prices.

Agriculture is one of the most hazardous occupations worldwide. In several countries the fatal accident rate in agriculture is double the average for all other industries. According to International Labor Organization (ILO) report, the intensive use of pesticides, ultraviolet (UV) radiations, extreme weather conditions, noise and vibrations from the machinery are the most frequent causes of hazards or illness to the farmers [27].

Thus it is essential that the lifestyles of farmers be improved. This is definitely possible taking into consideration the growing enthusiasm among them for e-governance and the technological advancements in ICT. We shall now see the proposed system of mobile application-arduino robot in more detail.

II. OBJECTIVES

As discussed earlier, there is a need to exploit the advances in ICT to foster e-governance which is important as the farmers need to work in tandem with the government and take full advantage of the services provided by it. The proposed mobile application acts as a farmer’s assistant in the field. It provides essential agriculture related information like weather forecasts, news, mandi (market) prices of crops to the farmer. There is also an in-built database in which the farmer can keep a track of his inventories, harvests, seeds and fertilizer purchases, vehicles and equipment, etc. To reduce the amount of field work for the farmer the application also offers wireless switching on-off of pumps for watering, irrigating. Wireless sensor network of soil moisture sensor, soil pH sensor and soil temperature sensor is connected to an Arduino Mega 2560 microcontroller board. The android application controls the pumps over GSM network via SMS (which enables pump control over long distances) and Bluetooth (when in close proximity for real time diagnosis of the sensor readings). We shall next see each feature of the application in detail.

III. SOFTWARE FEATURES

A. Registration and Signing into the application

The app requires the user to sign up with his mobile number and a 4 digit numerical password. The user is verified by sending a SMS to this number (i.e. itself) and detecting it. Upon successful verification, the registration details are written through a PHP script and HTTP Client Server APIs into a MySQL database [Fig 2] at a remote central server. Every time the user attempts to login, the database table is queried for the username-password pair and accordingly grants further access or not. The process is summarized in Fig 1.

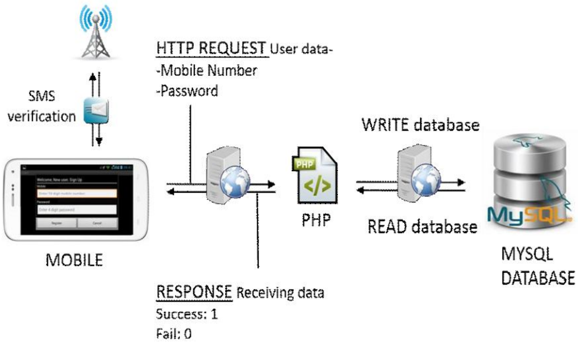
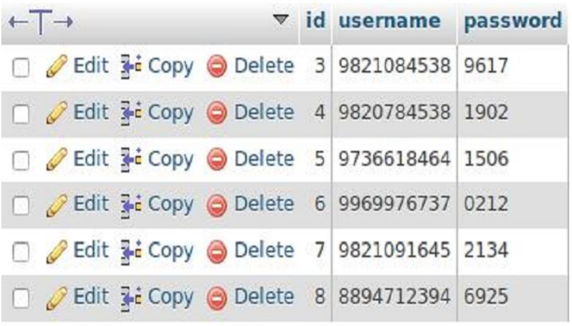


Fig 1: Registration and Sign In system for the app



	id	username	password
Edit Copy Delete	3	9821084538	9617
Edit Copy Delete	4	9820784538	1902
Edit Copy Delete	5	9736618464	1506
Edit Copy Delete	6	9969976737	0212
Edit Copy Delete	7	9821091645	2134
Edit Copy Delete	8	8894712394	6925

Fig 2: screen shot of MySQL table with the user info.

B. Weather Forecast

A HTTP Connection is made to the OpenWeatherMap web service [24] over WiFi/ GPRS which queries the data from OpenWeatherMap servers. The data which the client gets regarding forecast is in the Extensible Markup Language (XML) and JavaScript Object Notation (JSON) formats. XML provides a language which can be used between different platforms and programming languages and still it can express complex messages and functions. JSON is used primarily to transmit human-readable text consisting of attribute–value pairs between a server and web application. The weather data is in the form of Extensible Markup Language (XML) [Fig 5] which is parsed and displayed in the application screen. User can search based on current GPS location or directly by city name; the 16 days' forecast includes information about – weather type, image, min-max temperature, pressure, wind speed, humidity, clouds Fig 3]; graphical trend over the next week of various parameters are also available in the app for visual aid [Fig 4]. These data will enable the farmer to better plan his actions during the agricultural cycle like taking precautionary measures over a predicted hailstorm, and hence safeguard his interests.

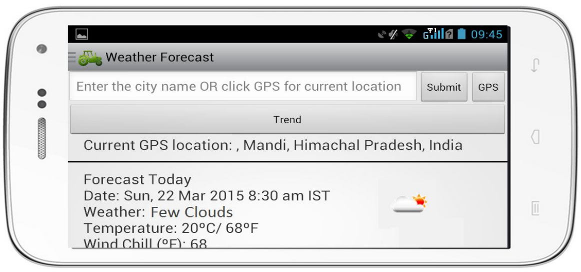


Fig 3: Forecast result for the current GPS location using the OpenWeatherMap free web service

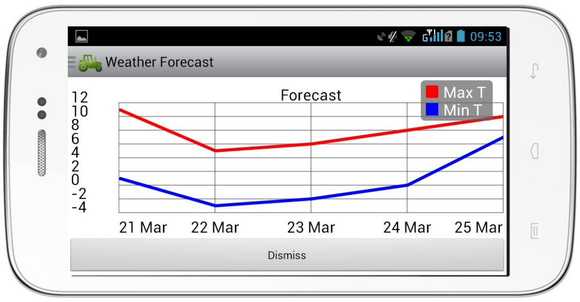


Fig 4: Graph trend of the max and min temperatures


```
{ "base" : "stations",
  "clouds" : { "all" : 0 },
  "cod" : 200,
  "coord" : { "lat" : 31.800000000000001,
      "lon" : 77.040000000000006
    },
  "dt" : 1430200651,
  "id" : 0,
  "main" : { "grnd_level" : 871.25999999999999,
      "humidity" : 60,
      "pressure" : 871.25999999999999,
      "sea_level" : 1023.33,
      "temp" : 296.24200000000002,
      "temp_max" : 296.24200000000002,
      "temp_min" : 296.24200000000002
    },
  "name" : "Mandi Sub-District",
  "sys" : { "country" : "India",
      "message" : 0.010699999999999999,
      "sunrise" : 1430179737,
      "sunset" : 1430227781
    },
  "weather" : [ { "description" : "sky is clear",
        "icon" : "01d",
        "id" : 800,
        "main" : "Clear"
      } ],
  "wind" : { "deg" : 285.00400000000002,
      "speed" : 0.92000000000000004
    }
}
```


Fig 5: current weather response from the webserver in JSON format for Kataula, H.P, IN

C. Commodity Market Prices

Agricultural commodities are traded in mandis (markets) at the district level. The government sets support prices to stabilize the prices but the Mandi prices are dynamic. The farmer, to access these prices enters the date, crop name and the Indian state. The application uses APIs provided by Ministry of Agriculture, govt. of India on Open Data to make HTTP requests to the web servers from where data in XML format is received, which, after formatting, is made available on the app in a human-readable form [23],[20] as shown in Fig 6. The application displays a table contains information about market (district name), arrival quantity (in MT), origin, variety, grade, minimum price, maximum price, and modal price (in Rs. / quintal) [Fig 7]. With a rough idea about the prices, the chances of a farmer being exploited and cheated are minimized.

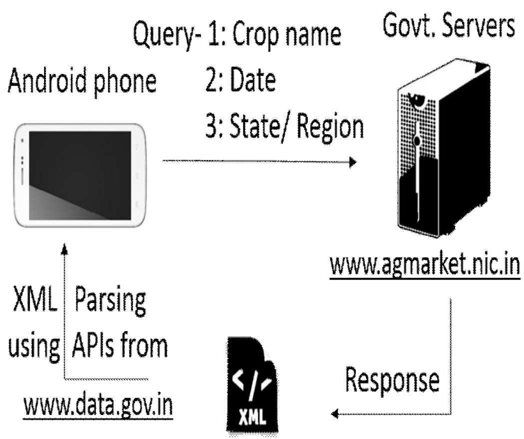


Fig 6: Client-server architecture of app retrieving crop prices

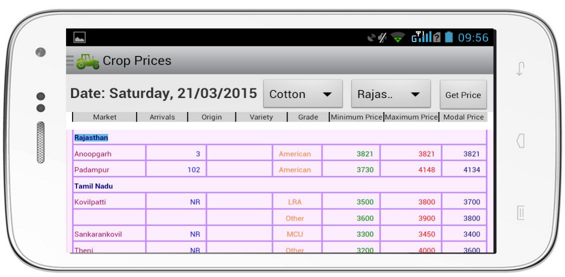


Fig 7: Result of the crop price search query

D. Agricultural News

Keeping oneself updated about the happenings in and around the world is essential in taking precautions or planning for a better produce. An HTTP Connection is made to the database/ web server over WiFi/ GPRS which gets the data from websites [6], [16]. The data is in the form of RSS Feeds which is parsed and then displayed in viewable form [Fig 8]. News are obtained using RSS feeds on 82 topics globally [6], national (pertaining to India) or regional (state-wise news) [16]. Clicking on the headlines takes the user to read the complete article.

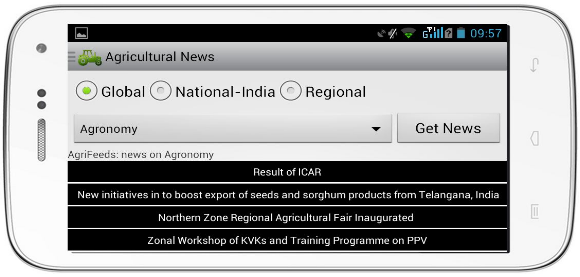


Fig 8: Result of the global news query on Agronomy

E. Map view of Field

Google Maps V2.0 API was used to display the area around the farmer's current position (supposedly near his field) [14]. The map features the terrain, normal, marker only views. The farmer can insert any markers to mark his field boundary. Also shown are the farmer and the robot's images at their GPS positions along with their speeds for better control [Fig 9]. There is also a map screenshot option to take timely snapshots during the crop cycle [Fig 10]. The farmer will not only be able to monitor his crop for any diseases, but also make plans for next steps based on the gradual growth phases captured.

Fig 9: Map showing user, robot and their speeds

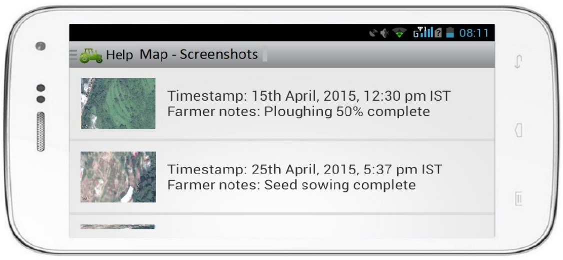


Fig 10: Database of screenshots of the field map taken

F. Farmer Helplines and Services

As stated earlier, the Indian government comes up with time to time schemes and farmer assisting centers fostering e-governance. E-governance is the effective transfer of knowledge and authentic information directly to the consumers/ other businesses. The Indian government has come up with Kisan Vikas Kendras (KVK), and Kisan Call Centres (KCC) as advisories to respond to issues raised by farmers instantly as well as continuously in their local languages [18], [17]. There is a toll free helpline of the KCC set up by the government at the farmers' disposal. The application provides the state wise addresses and contact information of the various KVKs [Fig 12] and KCCs [Fig 11] in the country. An evaluation study by Hanumankar (2011, cited by Saravanan, R 2014) asserts that there is considerable interest for ICT based agricultural extension services in the age group 29 to 48 years who use the KCC helplines most often [28].

Fig 11: Application displaying Kisan Call Center information

Fig 12: Application displaying Kisan Vigyan Kendra information

G. Farm Management

Farm Manager (Inventory management): The application has an in-built farm manager module as proposed by Liopa-Tsakalidi (2013) with which the user can better manage his field and crops [4]. The farmer can keep a track of his assets, inventories and also his cropping cycle.

1: Vehicles and attachments – name, id, purchase date, cost, last, next servicing dates [Fig 13]

2: harvested crops – name, quantity, harvest date, amount unsold and check date.

3: seeds and fertilizers - name, quantity, purchase date, cost, quantity remaining.

The app also generates alarms based on these dates to remind the farmer about upcoming servicing, maintenance dates. A SQLite database for android is used to manage (insert, edit, delete, view) the data. The SQLite database data cannot be directly viewed in common software so it is exported to the more common Microsoft Excel format (.xlsx) using Android APIs [Fig 14].

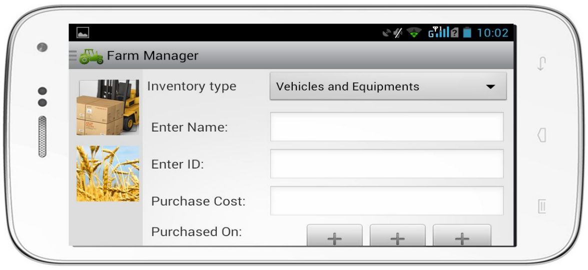


Fig 13: Database entry page with various I/P fields

	A	B	C	D	E	F
1	Vehicles and Equipments Database					
2	Name	ID	Cost	Purchase Date	Last Service Date	Next Service Date
3	Tractor	T-01	3,00,000	12-May-13	12-May-14	12-May-15
4	Rotavator	R-02	1,00,000	29-May-14	30-Nov-14	31-May-15
5	Plough	P-01	25,000	10-Jun-14	11-Dec-14	12-Jun-15

	A	B	C	D	E	F
1	Seeds and Fertilizer Database					
2	Name	Qty bought	Cost	Purchase Date	Qty Remaining	on
3	NPK 13:33:0:6	50000gm	800	30-Apr-14	40000gm	20-Apr-15
4	Brinjal	2000gm	23000	01-May-14	250gm	20-Apr-15
5	Cabbage	500gm	5750	06-Sep-14	0gm	20-Apr-15

	A	B	C	D	E	F
1	Harvest inventory					
2	Name	Quantity	Harvest Date	Worth	Amount unsold	on
3	Wheat	1MT	01-May-14	15000	0	20-Apr-15
4	Cabbage	1MT	06-Sep-14	12000	0.5MT	20-Apr-15

Fig 14: Database tables in Microsoft excel

IV.HARDWARE INTERFACE

A 4-wheeled robot prototype was fabricated to test controlling it wirelessly using an android cell phone. The robot moves with DC motors and is steered using a servo motor connected as an articulated steering [Fig 17].

A HC-05 Bluetooth module was connected to the same microcontroller to establish a duplex communication channel between itself and the android smart phone [Fig 16]. Data is encrypted, for example, into strings like <!"data"\n!> where "data" is the actual data for example – start; '<' is the start bit, '!' is the start confirm bit, '\n' is the end of data bit. Similarly, '!' is the end bit and '>' is the end confirm bit. This encryption is necessary to avoid any noise (fuzzy data) collected by the sensors from the environment. For example: The string value for going forward is <!"F"\n!> which turns the DC motors ON. Because this is a real time connection, there is continuous exchange of data at a high rate. The data from phone to Arduino controls the robot whereas the return channel contains real time data of the readings of the ultrasonic and infrared sensors [Fig 15].

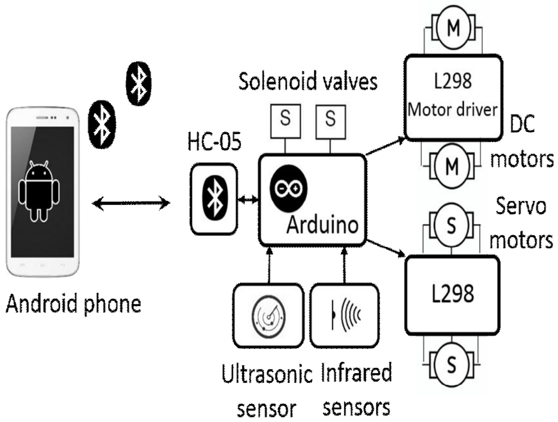


Fig 15: Architecture of the android-Arduino-sensors-actuators network

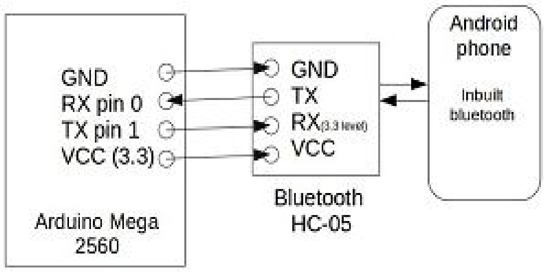


Fig 16: Block diagram of the Arduino Mega-android connections using HC-05 bluetooth module

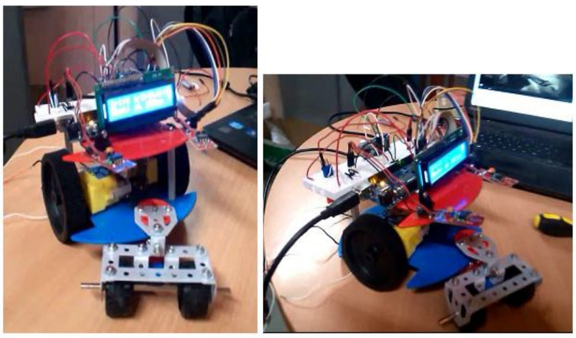


Fig 17: F.V. and S.V of current versions of the prototype

H. Obstacle avoidance and indicators

An ultrasonic sensor module is placed in the front of the robot continuously measuring distance to the nearest obstacle [Fig 18(a)]. Its range of operation was found to be <~200cm. 2 infrared sensor modules are placed on either side of the vehicle which toggle their states whenever obstructed by an obstacle [Fig 18(b)]. Real time data from these sensors is sent to the android smartphone via Bluetooth as well as to the computer over serial port. Real time graph is observed on the computer/ laptop through Processing IDE [Fig 19(b)] as well as on the android app using open source graphing libraries – AchartEngine and GraphView.

Data is also displayed on a 16x2 liquid crystal display (LCD) module fitted on the robot [Fig 19(a)]. A buzzer functions as a horn to alert human/ animal obstacles and light emitting diodes (LEDs) are also there acting as indicators.

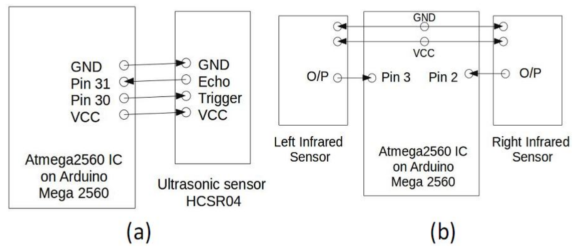


Fig 18 (a): Pin-connections of HCSR04 ultrasonic sensor module to Arduino mega. (b): Pin-connections of 2 (left and right) infrared (IR) sensor modules to Arduino mega.

Fig 19 (a): LCD screen displaying statuses of infrared, ultrasonic sensors; (b) The real time graph of ultrasonic sensor on Processing software on desktop

I. *Plough Mechanism*

A plough mechanism was attached to a servo motor fixed on the robot [Fig 21] whose angle was controlled by Pulse Width Modulation (PWM) signals from the PWM pins of the Arduino Mega2560. A unique property of a servo motor is to apply reverse torque to retain its position when under load. The farmer can currently control the depth of the plough by setting in the application UI [Fig 20]. The depth inputted calculates the angle moved by servo and hence the PWM value.

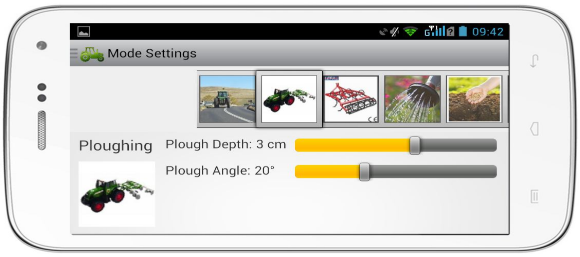


Fig 20: Application UI to set plough angle and depth

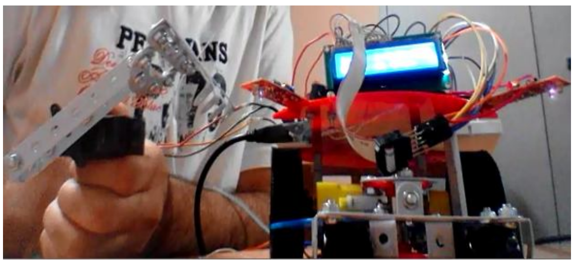


Fig 21: A plough mechanism connected to a servo motor

J. *Seed sowing mechanism*

A small container with small seeds opened by a latch controlled by a linear actuator is fitted on the bottom layer of the prototype. Currently, the seeding distance can be set by the farmer which is set in the android app [Fig 22]. It is maintained by calculating the vehicle speed and accordingly controlling the opening and closing of the latch operated by the linear actuator.

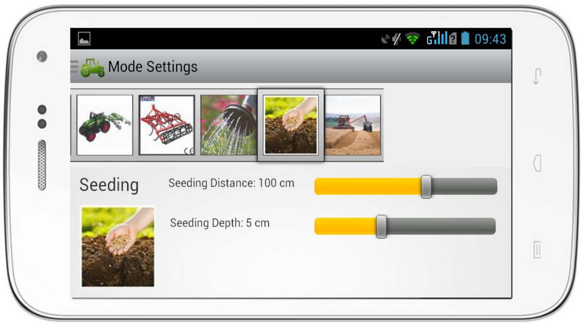


Fig 22: Application UI to set seeding distance and depth

K. *Wireless pump operations*

The mobile application is designed to establish a dual communication with an Arduino microcontroller controlled wireless sensor network and water pump. 2 types of wireless networks, namely GSM and Bluetooth, were used to establish this communication channel. 4 sensors measuring soil moisture, soil temperature, soil pH, and air humidity respectively are connected to the microcontroller and they send their data to the android application for diagnosis as well as appropriate decision making on operating the pumps [Fig 23]. A similar data logging and telemetry system was proposed by Lim, Wilton (2014) which involved data logging of only soil moisture and temperature [32].

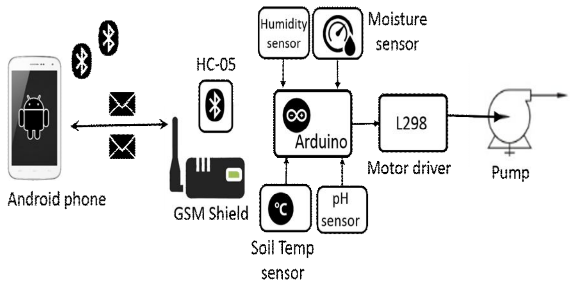


Fig 23: Architecture to control the pump and monitor the sensors over GSM as well as bluetooth

- Over GSM: The merit of using this communication channel is that it can be operated over long distances. An Arduino GSM shield with a SIM card was connected to the microcontroller and the wireless sensor network. The farmer queries for the status of the sensors before taking a decision. The SMS received from the microcontroller contains the current pump status and the sensor readings at that very instant. Taking stock of these readings farmer can remotely switch on-off the water pumps by setting the target soil moisture parameter [Fig 24]. The pump will be switched ON till the farmer specified soil moisture value is reached.

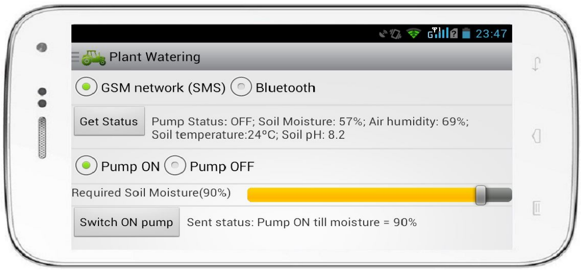


Fig 24: App UI to monitor sensors and control pumps over GSM network

- Over Bluetooth: When the farmer is at his field, he can directly connect the android application with the wireless pump system over Bluetooth. A HC-05 Bluetooth module was connected to the same microcontroller to establish a duplex communication channel between itself and the android smart phone. Data is encrypted, for example, into strings like <!“data”\n!> where “data” is the actual data for example – start; '<' is the start bit, '!' is the start confirm bit, ‘\n’ is the end of data bit. Similarly, '!' is the end bit and '>' is the end confirm bit. This encryption is necessary to avoid any noise (fuzzy data) collected by the sensors from the environment. For example: The string value for retrieving the sensor information is <!“57”,“69”,“24”,“8.2”\n!> which has the various sensor readings in the order of moisture, humidity, temperature and pH [Fig 25]. Because this is a real time connection, there is continuous exchange of data at a high rate. The application records the sensor readings every 2 minutes and graphs all the sensor readings over time for diagnosis [Fig 26]. The readings are also saved in a local sqlite database table only to be exported to the excel format later [Fig 27].

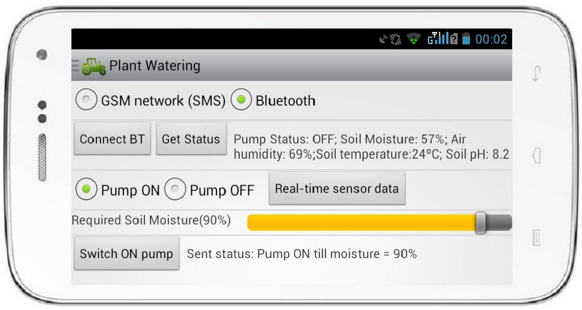


Fig 25: App UI to monitor sensors and control pumps via Bluetooth connection

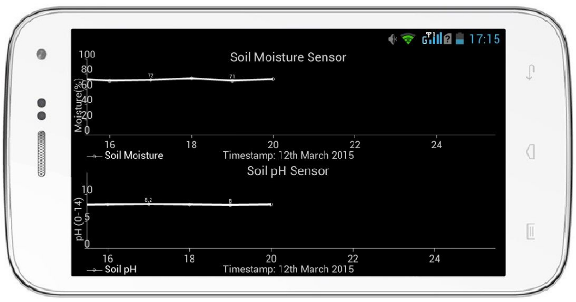


Fig 26: Real time graphs of sensors on the app screen when diagnosing using Bluetooth

	A	B	C	D	E
1	Timestamp	Temperature (°C)	Humidity (%)	Soil Moisture (%)	Soil pH (0-14)
2	12-03-2015 11:00	28.2	54	74	8.1
3	12-03-2015 11:02	28.1	54	73	8.3
4	12-03-2015 11:04	28.1	52	73	8.1
5	12-03-2015 11:06	28.4	53	72	8.1
6	12-03-2015 11:08	28.3	56	73	8.2
7	12-03-2015 11:10	28.2	55	74	8.1
8	12-03-2015 11:12	28.5	56	72	8.2
9	12-03-2015 11:14	28.1	51	72	8.2
10	12-03-2015 11:16	28.5	53	72	8.2
11	12-03-2015 11:18	28.3	56	73	8.2
12	12-03-2015 11:20	28	56	72	8.2
13	12-03-2015 11:22	28.1	56	72	8.1
14	12-03-2015 11:24	28.1	55	74	8.2
15	12-03-2015 11:26	28.4	54	75	8.1
16	12-03-2015 11:28	27.9	57	74	8.1
17	12-03-2015 11:30	28.2	56	73	8.2

Fig 27: Sensor data being tabulated for future use in sqlite database exported to Excel format

CONCLUSION AND FUTURE WORK

The availability of agricultural information directly in a farmer’s hand without him being dependent on neighbors or zamindars or even waiting for a SMS response from the mKisan portal like schemes, will enable the farmers to take better decisions in short time. This will not only foster greater productivity but will improve a farmer’s life reducing stress and also instilling zeal to learn new technology which is essential in this era of Digital Revolution. Some other areas of agriculture whose information is frequently required by farmers are about seeds and fertilizers, the loan schemes, etc. The application currently is offered in 8 Indian regional languages but agricultural data from web services is only in English. Future versions and work on the application will be to incorporate the above features. Switching pumps on and off from the comfort of one’s house or while away from town will enable multitasking reducing time wastage and hence more productivity. Collection and documentation of sensor data can only help better predict future behaviors. A wireless seed sowing cum irrigating cum ploughing robot can only help a farmer by not adversely affecting his health. Future work will be to build a commercial sellable product with possible additional features like harvesting, or a video camera sending live video feed to the farmer’s cellphone via an IP Camera. Use of Radio Frequency (RF) and WiFi Network can increase the operational distance of the vehicle but involves high costs and less accuracy with high risks. Future work will be application of these communication networks.

REFERENCES

[1] Aadhar Project, Government of India; http://www.uidai.gov.in

[2] Abdullah, F. A., & Samah, B. A. (2013). Factors impinging farmers’ use of agriculture technology. Asian Social Science, 9(3), p120.

[3] AChartEngine http://www.achartengine.org/

[4] Liopa-Tsakalidi, Aglaia (2013) Dimitrios Tsolis, Pantelis Barouchas, Athanasia-Eleftheria Chantzi, Athanasios Koulopoulos, Nikolaos Malamos Application of Mobile Technologies through an Integrated Management System for Agricultural Production: Proceedings of the 6th International

Conference on Information and Communication Technologies in Agriculture, Food and Environment (HAICTA 2013)
[5] Agricultural Products in India, Available: http://www.agriculturalproductsindia.com/agro/introduction.html Accessed: 12th April 2015
[6] AgriFeeds http://www.agrifeeds.org
[7] Arduino http://www.arduino.cc
[8] Central Statistics Office, Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India, "Pocket Book of Agricultural Statistics- 2014", pg. 23- Available at: http://www.eands.dacnet.nic.in/latest_2006.htm
[9] Chandra, D.G.; Malaya, D.B. , "Role of e-Agriculture in Rural Development in Indian Context," Emerging Trends in Networks and Computer Communications (ETNCC), 2011 International Conference, pp. 320 – 323, 2011.
[10] Department of Agriculture and Cooperation: http://agricoop.nic.in/aboutus.html
[11] Economic Survey 2010, pp.180 Available: http://en.wikipedia.org/wiki/Economy_of_India#CITEREFEconomic_Survey2010
[12] Economic Survey 2013-14 and CSO, Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India, "Pocket Book of Agricultural Statistics - 2014", pp. 19 -Available: http://www.eands.dacnet.nic.in/latest_2006.htm
[13] e-Agriculture: http://www.e-agriculture.org/e-agriculture
[14] Google Maps API https://developers.google.com/maps/
[15] GraphView library: http://android-graphview.org/
[16] indiatogether http://indiatogether.org/rss_feeds_list
[17] Kisan Call Centers, Ministry of Agriculture: http://agricoop.nic.in/policyincentives/kisancalldetail.htm
[18] Krishi Vigyan Kendra, Ministry of Agriculture: http://www.icar.org.in/en/krishi-vigyan-kendra.htm
[19] Kumar, D. (2005). Information and communication technology (ICT) in Indian agriculture (No. 0503002). EconWPA.
[20] Ministry of Agriculture, Govt. of India http://www.agmarket.nic.in
[21] Ministry of Agriculture, Govt. of India, Detailed Writeup on mKisan Portal. Available at: http://www.mkisan.gov.in/images/Detailed%20Writeup%20on%20mKisan.pdf
[22] Mittal S., Gandhi S., Tripathy G., (February 2010) Indian Council For Research On International Economic Relations, Working Paper No. 246 -"Socio-Economic Impact of Mobile Phones on Indian Agriculture" Available: http://www.mobileactive.org/files/file_uploads/Impact%20of%20Phones%20on%20Indian%20Agriculture.pdf
[23] Open Government Data (OGD) Platform India, http://www.data.gov.in
[24] OpenWeatherMap API for developers: https://openweathermap.org/
[25] Patil, Gangadhar S, Indiaspend.org (April 2015) Rural India leads record 35% surge in use of e-governance. Business Standard, 22 April 2015. Available online at: http://www.business-standard.com/article/specials/rural-india-leads-record-35-surge-in-use-of-e-governance-115042200378_1.html
[26] S. Chen, B. Mulgrew, and P. M. Grant, "A clustering technique for digital communications channel equalization using radial basis function networks," IEEE Trans. on Neural Networks, vol. 4, pp. 570-578, July 1993.
[27] Safe Work, Labor Protection Department, International Labor Organization "Safety and Health in Agriculture" Available: http://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/publication/wcms_110193.pdf
[28] Saravanan, R., and Suchiradipta Bhattacharjee, "Mobile Phone Applications for Agricultural Extension in India," In: Saravanan, R (Ed.), Mobile Phones for Agricultural Extension: Worldwide mAgri Innovations and Promise for Future, New India Publishing Agency, New Delhi. pp. 1-75, 2014
[29] Singhal, M., Verma, K., & Shukla, A. (2011, December). Krishi Ville—Android based solution for Indian agriculture. In Advanced Networks and Telecommunication Systems (ANTS), 2011 IEEE 5th International Conference on (pp. 1-5). IEEE.
[30] Survey by a digital marketing agency, Webenza – Available: http://www.webenza.com/android-vs-ios-smartphone-users-in-india-2014-infograph/
[31] T.V. Prabhakar, H.S. Jamadagni, B.S. Sudhangathan (2013), "Datamule For Agricultural Applications," India Educators' Conference (TIIEC), 2013 Texas Instruments, pp. 369 – 373, 2013
[32] Wilton. Lim, Hans Kaell Torres, Carlos M. Oppus - "An Agricultural Telemetry System Implemented Using an Arduino-Android Interface," 7th IEEE International Conference Humanoid, Nanotechnology, Information Technology Communication and Control, Environment and Management (HNICEM); IEEE Philippine Section 12-16, November 2014, Philippines
[33] World Bank Data: Employment in Agriculture (% of total employment) Available at: http://data.worldbank.org/indicator/SL.AGR.EMPL.ZS
[34] Zhan. Wei. Siew, Chen. How. Wong, Shee. Eng. Tan, Hou. Pin. Yoong, and Teo. K.T.K. "Design and development of a tablet based real time wireless data logger," Global High Tech Congress on Electronics (GHTCE), IEEE, pp. 111 - 116, 2012
[35] Singhal, Manav, Kshitij Verma, and Anupam Shukla. "Krishi Ville—Android based solution for Indian agriculture." Advanced Networks and Telecommunication Systems (ANTS), 2011 IEEE 5th International Conference on. IEEE, 2011.
[36] Kissan Kerala, http://www.kissankerala.com

★★★