Design Architecture of Autonomous Precision Farming System

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***Abstract*— Precision farming technology is a valuable management concept that aids accurate soil parameter monitoring & control. Automation allows farmers to apply optimal amount of water and fertilizers at the field locations upon requirement. This paper describes the design and development of an Autonomous Precision Farming System (APFS) for agriculture automation. It is a low power, user friendly system which helps the farmers to plan irrigation and fertilization based on environmental and soil conditions. The system can intelligently operate pumps / valves based on the data available from the field and the preloaded programs available in the controller. APFS monitors and maintain the various farming parameters like soil moisture, pH level, atmospheric temperature, humidity, fertilizer concentration etc. and appraises the information to farmers. APFS features Wireless data acquisition through wireless motes. The graphical TFT touch screen provides responsive user interface. The farmers can configure the device for getting alerts of critical field parameters or hazardous conditions. These alerts can be conveyed to the farmer in the form of preprogrammed text Messages to his mobile phone through SMS. The system also incorporates mechanism for controlling the agricultural field equipment from a remote location through DTMF technique using mobile phones.**

Keywords— Soil Moisture, pH, Atmospheric Temperature, Humidity, Precision Farming System, TFT, ZigBee, GSM

I. Introduction

In recent years, we have seen an ever-growing demand of process automation in irrigation systems. These systems could ensure appropriate water management by measuring and processing various environmental factors and soil parameters and thereby minimizing its wastage. This enables the farmer, to obtain an optimized result. Precision farming is one of the latest practice adopted worldwide for efficient water management. It implies knowledge-based agriculture, employing the latest techniques of science and technology bringing together diverse fields. The plants can be cultivated in an ideal condition, ensuring the plant never suffers from over nutrients or deficiency, thus enhancing quality, optimum growth and high yield. The concept of precision farming is spreading fast in developing countries as a methodology to meet the challenge of sustainability in agriculture. Precision farming is generally defined as information and technology based farm management system to identify, analyze and manage variability with in fields for optimum profitability, sustainability and protection of the land resource.

Agricultural production system is an outcome of a complex interaction of seed, soil, water and agro-chemicals and fertilizers. The sustainability of such a complex system depends on the judicious management of all these inputs. The only alternative left to enhance productivity in a sustainable manner from limited natural resources, without any adverse consequences, is by maximizing efficiency of available input resources. It’s high time to exploit all the modern tools by bringing information technology and agricultural science together for improved economic and environmentally sustainable crop production. Precision agriculture merges the new technologies borne of the information age with a mature agricultural industry [1]. The key factors which keeps the new generations away from cultivation are the boring activities of continuous monitoring, watering, fertilizing, above all the scarcity of skilled workers, and higher operating costs.

In this paper an efficient solution for maintaining the water and nutrient supply to the crop fields based on the climate and soil conditions has been proposed. The proposed ARM based system incorporating GSM technique enables farmer to control the system remotely, based on the field parameter updates received in his mobile phone. The user communicates with the centralized unit through GSM/GPRS services [6]. This energy efficient module provides a progressive path of

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adaptive migration to tomorrow's advanced automation systems in agriculture. It competes with the products of pioneers in agriculture automation in terms of salient features and tops the above with respect to cost effectiveness. The proposed system helps to transform the agricultural sector by maximizing the yields with no or minimum manual intervention.

II. PROPOSED SYSTEM

In conventional methods of farming, the entire soil surface is saturated with fertilizers and often stays wet long after the irrigation is completed. Using precision farming technique, we can apply droplets of water along with the required fertilizers to the plant root directly. The proposed system architecture comprises of facility to interface different sensors which sense various agricultural parameters like temperature, humidity, pH range and moisture content of the soil. Depending upon the sensed parameters, the APFS system will take the necessary action in accordance with pre-loaded configuration.

APFS incorporates three modes of operation namely Automatic mode, Manual mode and Remote mode. In automatic mode farmer will not be directly involved in controlling field equipment. As per the preloaded configuration and sensed/measured values, APFS automatically manages the field parameters and field operations. In manual mode farmer will be directly controlling the field equipment using the built-in TFT display. In remote mode farmer can control the field equipment through his mobile phone using DTMF mechanism. Automation of irrigation system is gaining importance as there is a huge need to use water resources efficiently and effectively. The system is used to turn the valves ON or OFF automatically as per the water requirement of the plants. The system is capable of sensing, monitoring, controlling and communication. The main functional requirements of system include,

1) Monitoring of various agricultural parameters like Temperature, Humidity, pH value, Soil moisture etc using corresponding sensors.
2) Irrigation and fertilization planning can be done on hourly, daily, weekly monthly and yearly basis.
3) Wireless data collection through ZigBee nodes.
4) Send SMS messages to the farmers' cell phone for providing situation awareness regarding the agricultural field, while he is away from field.
5) Provision to operate agricultural field equipment using mobile phone from a remote location.
6) External memory interface for Data logging and program feeding.

III. BLOCK DIAGRAM DESCRIPTION

Fig. 1 depicts the block diagram of the proposed system.

A. Microcontroller

The microcontroller controls the logic flow of the system. The master program is stored in the flash memory, while an EEPROM (Electrically Erasable Programmable Read Only Memory) is used to store the user authentication details and the phone number.

B. Power supply

12V DC is given as input for the system. Dual channel monolithic synchronous step-down regulator IC is used to generate the required voltage levels of 3.3V and 9V with 3A output current capability per channel.

C. RS232/485

RS-232 serial port is a standard feature to debug and interface other peripheral devices. UART of the processor can be configured as RS-232 to enable debugging and printing. Two channels UART is used for communication in RS485 mode, one channel is being used for redundancy.

D. Analog input

The different sensor values are taken as the analog input (AI), here the current values are taken from the sensors. It ranges from 4 to 20mA and converted to the analog voltage ranges from 1 to 5V.

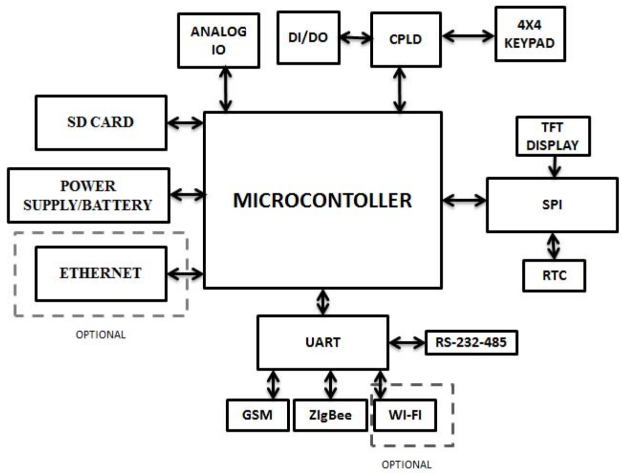

Fig. 1. Block diagram of proposed system

E. Analog output

The analog output (AO) is used for percentage wise opening and closing of valves automatically to maintain precise amount of water and fertilizers as per the requirements of the plants.

F. Digital input

Digital input (DI) circuits will give the status of the system. Valve status (open/close) can be checked using this circuit.

G. Digital output

Digital outputs (DO) are typically used to provide on/off solenoid control valves, pumps, fans etc.

H. SD Card

An SD card reader is a device used to read data from Secure Digital or SD memory cards. These cards can be used for data logging and it also holds the program configuration to carryout field operations automatically.

I. GSM module

The GSM communication interface can be used to obtain alerts in the form of preprogrammed SMS messages by the farmers even when he is off field. This can also be used for getting the information such as water quantity used for irrigation, fertilizer quantity applied to the soil, daily log of field operations etc.

J. ZigBee

ZigBee based analog nodes can be used to collect the analog input values from the field and these values are send to the controller for further processing. This technology allows devices to communicate one another wirelessly with very low power consumption, allowing the devices to run on standard batteries for several years. It is designed to interact with the remote controlled devices, which are put under a single standardized control interface that can interconnect into a network.

K. Wi-Fi

WiFi interface is an embedded module based on the UART serial bus that works in accordance with the WiFi wireless WLAN standards, it accords with IEEE802.11 protocol stack and TCP / IP protocol stack, and it enables the data conversion between the user serial and the wireless network module through the UART-WiFi module.

L. RTC (Real Time Clock)

Real time clock (RTCs) are the clock modules to provide precise time and date which can be used for various controlling and data logging applications.

M. TFT DISPLAY (Thin Film Transistor)

The user can give input or control the APFS system through simple or multi-touch gestures by touching the screen with a special stylus and/or one or more fingers. It also gives a situational awareness of field parameters through the graphical user interface.

N. CPLD (Complex Programmable Logic Device)

A Complex Programmable Logic Device (CPLD) is a combination of a fully programmable AND/OR array and a bank of macro cells. APFS uses CPLD for connecting more digital inputs and output pins.

O. Ethernet

Ethernet, a local-area network (LAN) architecture uses a bus or star topology and supports data transfer at rates of 10 Mbps. The Ethernet specification served as the basis for the IEEE 802.3 standard, specifies the physical and lower software layers. Ethernet uses the CSMA/CD access method to handle simultaneous demands. An Ethernet network provides the flexibility of interfacing APFS with a computer or server system.

IV. SYSTEM ARCHITECTURE

The hardware includes Processor board, GSM, ZigBee and WiFi boards. It contains the Analog input channels, Analog output channels and Digital input channels and Digital output channels. For communication interface it contain two configurable RS232/RS485 interface and a DTMF circuitry. On the GSM communication board, SIM900A modem is used. The system block diagram is as shown in Fig. 2.

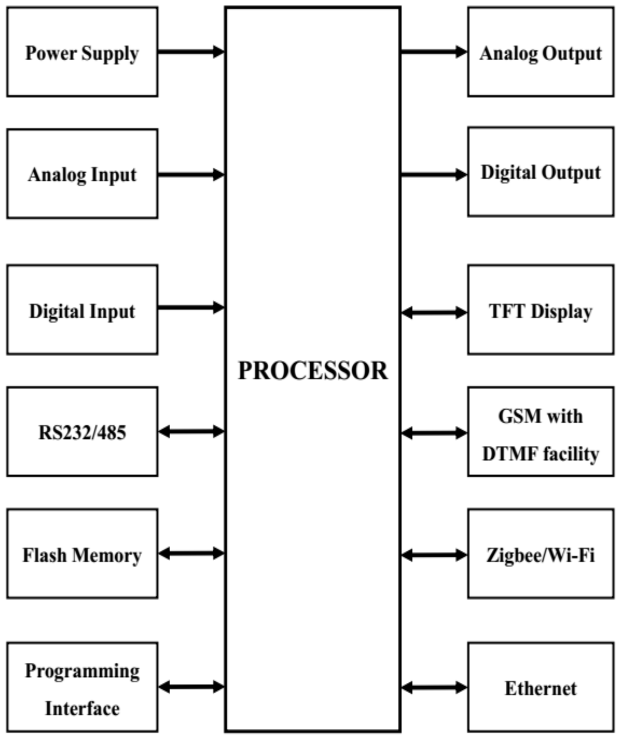

Fig. 2. System architecture of proposed system

The APFS system can intelligently operate pumps / valves based on the data available from the field and the preloaded programs available in the controller. The programs can be fed to the controller through either the inbuilt TFT touch interface or external memory interface. Situation based commands for controlling the agricultural field equipment from a remote location can be given through mobile phones.

The farmers will also be interested in getting the information such as water quantity used for irrigation, fertilizer quantity applied to the soil etc. APFS system can be configured for providing the log of these parameters on a daily /monthly basis. Pump switching operations and Valve openings can also be configured for logging. The logged data can be retrieved for further analysis using external memory interface.

V. FIRMWARE ARCHITECTURE

The firmware of APFS is built around the tiny Real time operating System (RTOS) called freeRTOS. The freeRTOS is one of the royalty free RTOS available. The entire functions of the APFS system is scheduled and controlled by the core of the freeRTOS. The block diagram representation is shown below. The programmed process control algorithms are used for the agriculture parameter control. The main functionalities of the APFS system are split into six different tasks. A simplified view of the operation of an APFS and the functions of the elements is shown in Fig. 3. The critical scheduled tasks in APFS system are

1. IO_Scan Analog
2. IO_Scan Digital
3. Loop Execution
4. Wireless Communication (GSM)
5. External Storage
6. Display / Touch Task

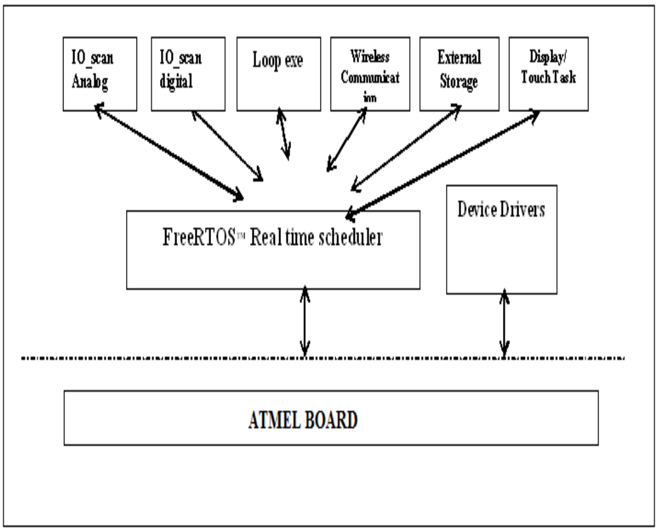

Fig. 3. Firmware Architecture

The 'IO_Scan Analog' task has two responsibilities; to sample data inputs using ADC and to provide analog output through DAC. This task is repeated every 100 ms. For each 100 ms the IO_scanAnalog () task reads the holding registers of the ADC module and if the memory access semaphore is free, the data is stored to memory. The IO-Scan Digital reads the digital register values of the processor. Also it gives the digital output values to the corresponding registers.

Loop Execution task executes & process the scanned input values. On power up, the APFS system loads the configuration from the SD card. The output of the loop execution will be given to the corresponding Digital / Analog output channels. The loop execution task is programmed in such a way that, it executes for a period of time and then goes to an idle state. The idle state time ensures the settling of agriculture factors like soil moisture and atmospheric temperature etc

The Display Touch task has mainly two functionalities, viz, the resistive touch interface used to decode the co-ordinates of the touch screen and the graphical User interface (GUI). All the touch interrupts are serviced through this task. Also the TFT display characteristics are controlled through this task. The Wireless communication (GSM) task manages the GSM communication. It is responsible for enabling the SIM card and establishing the communication with the existing GSM provider. This task is also responsible for the decoding of DTMF signals during remote operation mode. The GSM task also get activated every time when the farm parameters has to be send to the pre-configured farmer's mobile number.

VI. RESULT

Different sensors are used to detect the different aspects of the soil like temperature, humidity, pH of soil and moisture content of the soil. The APFS collectively acquire the various inputs from different sensors. Depending on the current cultivation, different control algorithm can be implemented based on nature of soil and atmospheric conditions.

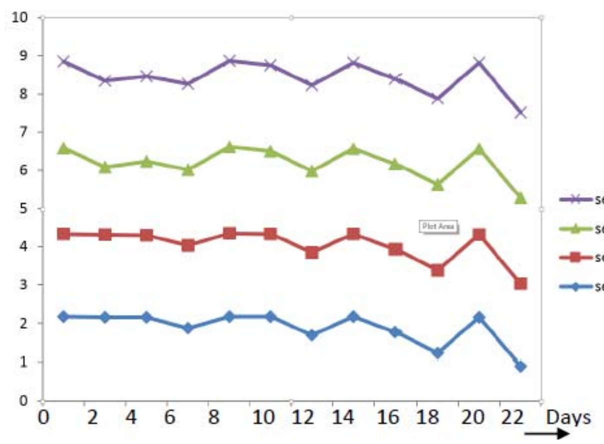

Fig. 4. Sensor calibration data

The APFS can operate in three generic modes of operation. In AUTO mode, the system collects data from different sensors and execute the pre-loaded control algorithm. The valves and pump get controlled automatically. It always ensures the required threshold levels. It also ensures to provide enough settling time so that the soil absorption behavior also taken into consideration. In MANUAL mode, the pump and valve operation are controlled on the basis of commands received through the touch panel. Here the ON/OFF condition for the valves and pumps does not depends on the sensor values, instead it fully depend on the manual commands. However, as a precaution, an 'OFF' time similar to that in AUTO mode is also provided. The OFF time ensures timely switch off of the agriculture equipment. In REMOTE mode, the farmers can control the field equipment from the comfort of home. The farmers can operate different equipment by giving commands from his mobile phone. Similar to MANUAL mode, a preprogrammed 'off' time is provided as a precautionary measure for human error.

A group of four soil moisture sensors are used for the system calibration. The values of the sensor at various instance of time get logged in the SD card. The graph in Fig. 4 shows the sensor values over a period of 25 days. As the soil get dried up i.e. when the curve moves upward and reaches the threshold average value, the valve and pump opens and watering get started. Similarly, as the soil get enough water i.e. as the curve reaches minimum average value, the water supply is stopped instantaneously.

VII. ADVANTAGES

The nutrients are supplied in required quantities at critical phases of plant growth to maintain the vigor of plants throughout the crop period. The uniform field stand of the crop helps the farmer to obtain 45 to 50 per cent increased marketable yield compared to the conventional system of cultivation.

By using drip irrigation, the farmers were able to save 40 to 60 percent of irrigated water when compared to surface irrigation. Thus, the farmers could increase the area under irrigation with the savings in irrigation water.

The APFS system is cost-effective compared to other international products available in market of comparable nature. Since the development is indigenous any technology advancements required can be carried out cost effectively and at lesser turnaround time. Most of the international products presently available in market are not suitable for Indian conditions.

VIII. FUTURE ENHANCEMENT

By engaging an APFS system by using upcoming techniques a farmer can increase his profit by solving different problems that are faced by the farmer in his routine life. User interface can be improved by incorporating a system with video capturing facility about the crop position and transmitting it by using MMS for further analysis and expert outlook. Development of a mobile app will ease the farmer's day to day activities at field.

IX. CONCLUSION

This paper presents the salient features of the in-house developed autonomous system and its wide scope in the field of agriculture in a developing country like India. The simplicity, modularity, ease of customization and ease of operation of these APFS modules makes it a proper solution for precision farming that can be used for the efficient water and fertilizer management without manual intervention. APFS system can monitor and control different farm constraints like soil moisture, pH, atmospheric temperature, humidity etc and update the information to the farmer. The system provides a real time feedback control based on the sensed parameters. The farmers are freed from the mundane activity of physical monitoring of field parameters. The system design philosophy, architecture of hardware and software had been discussed. It provides, a single compact controller based advanced control features, user friendly GUI, communication features, device inter-operability, and cost effectiveness.

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