An Automated Scheme for Precision Agriculture through Data Acquisition and Monitoring System using Multiple Sensors Network

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ABSTRACT
The Precision Agriculture is achieved by collecting & analyzing data from the agricultural field which is done in order to select the crops for specific terrain and particular season. The most advantageous part of the scheme is that it facilitates the farmer to get the field related information in advance to take correct decision on crop selection and irrigation in proper time and it also helps the agricultural scientists in their research works. In this paper there we explained an experimental set-up which is PC based wired network of 'Multiple Sensors' used to monitor and analyze consistently measured field data. Here our effort is accumulated to utilize a simplest technique for 'data acquisition' and monitoring of field temperature and moisture of soil by using LM35 (temperature sensor) and 'impedance moisture sensor' respectively.

General Terms
Precision Agriculture (PA), Multiple Sensors.

Keywords
Precision Agriculture (PA), Multiple Sensors, Data Acquisition, Impedance Moisture Sensor.

1. INTRODUCTION
Now-a-days through out the world the concept of "Precision Agriculture" is used in agricultural field which is evolved gradually day to day by incorporating some new technologies of modern electronics, instrumentation, telecommunication systems along with reliable information technology. Many definitions and ideas exist about precision agriculture (PA). According to the definition of US House of Representatives, 1997, precision agriculture is an integrated information and production-based farming system that is designed to increase long term, site-specific and whole farm production efficiency, productivity and profitability while minimizing undesired impacts on wildlife and the environment. According to the second definition, PA is a technological aspect where decisions on resource of agriculture are improved depending on the soil quality, crop requirements and environmental or climatic status as they vary at different fields and regions. Also to be mentioned that decisions are taken in such a way that it can supply better production utilizing optimized resources with minimum expenditure and minimum effect on environment. In a word, actually precision agriculture is a site-specific crop management (SSCM) technique. Therefore the targets of precision agriculture are -

a) Optimized production efficiency b) Optimized quality of crop c) Minimized environmental impact d) Minimized risk in production.

Hence the main goal of precision agriculture is to take the correct decision about the environmental condition of the region (nature of soil, soil temperature, soil moisture, relative humidity ambient temperature, rain gauge, day length, air flow etc) selected for crop cultivation to get optimized production. So we need continuous monitoring system using PC or micro controller, which can deliver continuous data to process, analyze or to take correct decision for crop selection according to the environmental condition zone wise. Moreover to sense various environmental parameters like temperature, moisture etc it is required to various types of sensors which may be integrated into a single structure called multiple sensors. The growth of crops mainly depends on the various environmental parameters; among them two important parameters for proper growth and life cycle of plant are ambient temperature and soil moisture. Therefore we have concentrated our experiment to monitor these two parameters continuously on a PC based monitoring system which can store the measured data and shows them continuously graphically or digitally.

2. PROPOSED ARCHITECTURE

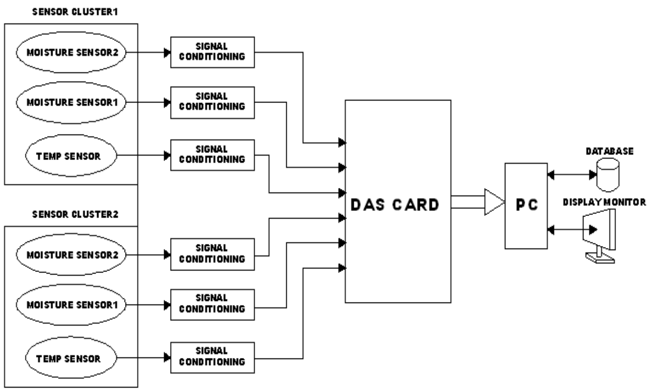


Fig.1: Block schematic of our entire system

2.1 Sensor Selection Criteria:

In our experiment we have used a multiple sensor which actually consists of two types of sensors – one is for measuring the environmental temperature and another is for measuring the moisture content in the soil. Hence there are so many types of temperature sensors like RTD, thermocouple, thermistor, semiconductor ICs, but here we have selected the semiconductor IC as temperature sensor, because of its satisfactory resolution, linear response up to a certain temperature range, easy interfacing circuitry etc. For this purpose, we have selected LM35 as semiconductor temperature sensor. The comparison study between the response curves of thermocouple, RTD, thermistor and LM35 is shown in Fig.2.

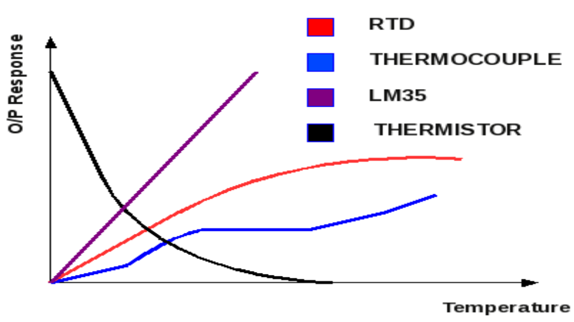


Fig.2: Response curves of RTD, Thermocouple, Thermistor, LM35

The temperature ranges of RTD, thermocouple, thermistor and LM35 are given in Table.1.

Table.1: Temperature ranges of various types of temperature sensors

Temperature sensors	**Temperature range**
RTD	250ºC – 850ºC
Thermocouple	0ºC – 1500ºC
Thermistor	-100ºC – 300ºC
LM35	-55ºC - 150ºC

The equations establishing the relation between measured temperature and outputs of various types of temperature sensors are given below.

RTD:

$R_T = R_0 (1 + C_1T + C_2T^2 + ...+ C_nT^n)$ ------- (1)
[R_T = output resistance, R_0 = resistance at temperature T = 0ºC, T = temperature in ºC]
Thermocouple:
$E = C_1 (T_2 – T_1) + C_2 (T22^- T_1^2)$ ------------------- (2)
[E = output voltage of thermocouple,T_1, T_2 = temperatures of two different junctions]
Thermistor:
$R_T = R_0 \exp [\beta (1/T – 1/T_0)]$ ------------------------- (3)
[R_T = resistance of thermistor at TºC,
R_0 = resistance of thermistor at 0ºC,
T_0 = initial temperature]

From the comparison curves of various temperature sensors shown in Fig.1 and from the above response equations of temperature sensors, it can be observed that although the environmental temperature range satisfies with the temperature ranges of thermocouple, RTD and thermistor, but the response curves in this temperature range is highly non-linear where the response curve of LM35 is almost linear in this temperature range with good responsivity. That is why we have selected LM35 as our temperature sensor to measure the ambient temperature. Moreover the cost of LM35 is low also.

Next we have chosen a impedance moisture sensor to sense the moisture content in the soil. Though there are various types of moisture sensors available like chilled mirror moisture sensor, hydrocarbon dew point sensor, we have selected it due its simple, small structure, high sensitivity, simple interfacing circuitry and easy mounting technique on the land.

2.2 Sensor Structure & Mounting In Field:

There are two types semiconductor temperature sensor – one is temperature sensitive voltage sources and another is temperature sensitive current sources. LM35 is temperature sensitive voltage source. Actually LM35 is a precision integrated circuit with high temperature sensing capability, whose output voltage is linearly proportional to the temperature of the medium where it is mounted and its output voltage is calibrated in degree Celsius temperature scale. LM35's low output impedance, linear output and precise inherent calibration in degree Celsius make interfacing to readout or control circuitry especially easy. LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is available in an 8-lead surface mount small outline package and a plastic TO-202 package. Some important features of LM35 IC are given below:

a) Calibrated output in Celsius.
b) Sensitivity is quite high, 10mV/ºC.

c) 0.5ºC accuracy guaranteed at 25ºC.
d) Long temperature range -55ºC to 150ºC.
e) Wide supply voltage range, 4V to 30V.
f) Less than 60µA current drain.
g) Low output impedance, 0.1 ohm at 1mA load.
h) Low cost and great availability in market.
i) Suitable for long distance transmission also.

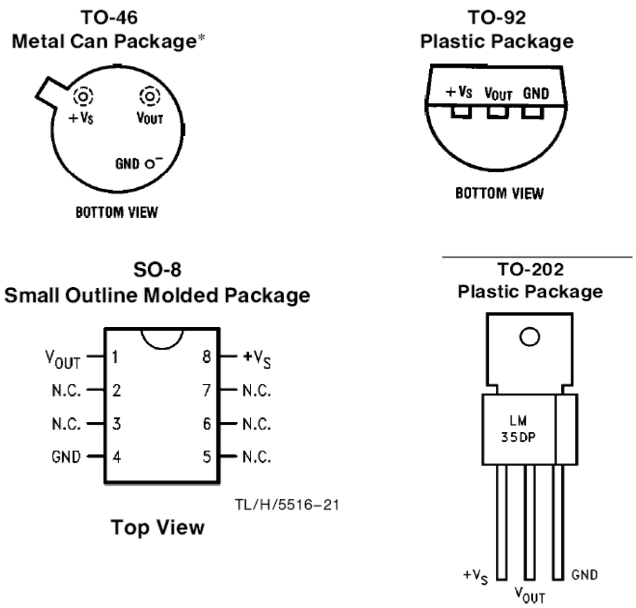


Fig.3: Various packages of LM35 IC

Another important point is the construction of our moisture sensor whose working principle depends on the impedance moisture sensor technology. Modern impedance dew point sensors are constructed with two conducting porous thin layers and a porous non-conducting thin film is sandwiched in between two conducting layers. This total assembly is placed on the top of the base of a ceramic substrate. Now the conducting porous layer allows the water vapor or moisture content of the soil to be transmitted to the active sensor layer. As a result the impedance of the active layer is changed due to the adsorption of moisture by it and this change of impedance is detected by some interfacing circuitry and also the moisture content can be detected. The construction of impedance moisture sensor is shown in Fig.4.

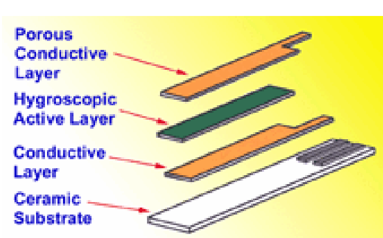


Fig.4: Construction of impedance moisture sensor

In our system, we have used two sensor clusters connected to a PC through an interfacing circuitry. The two sensor clusters are 70 ft apart from each other approximately and the distance of each cluster is 50 ft approximately as shown in Fig.5 schematically.

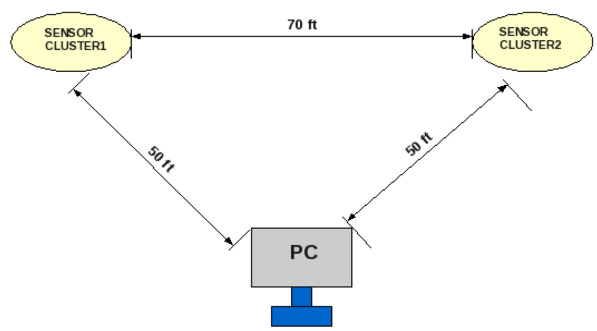


Fig.5: Sensor clusters location in our system

In each sensor cluster, we have used one temperature sensor on the surface apart from the plant to get the surrounding temperature, and two moisture sensors – one placed on the surface near the root of the plant whereas the other one below the surface near the bottom of the root of the same plant. The deep sensor is used to indicate the depth of penetration of water after irrigation, depending on the reading of the sensor the irrigation can be increased or decreased.

2.3 Signal Conditioning

There are six signal conditioning circuits as a total; therefore each sensor has its own signal conditioning circuitry. In this block, the signal received from the sensor is amplified, filtered and its gain and span are adjusted in such a way that it can be fed to the DAS card. Actually in our experiment that signal span is adjusted to 0 – 5 VDC.

2.4 Interfacing & Data Acquisition

Designing the Data Acquisition System or DAS card is a vital part of our entire system. The purpose of DAS card is convert the analog signal achieved from sensors to its 8-bit digital form and delivers the digital data to a PC. Actually our DAS card is capable to handle eight analog signals at most at its eight input channels. Here six input channels are used to convert the signal to their digital equivalents, as we have used six sensors, so remaining two input channels are not used and kept unconnected. For this purpose, ADC0808 is used. ADC0808 has eight input channels and these channels are selected by PC through its parallel port. At a time only one channel is selected and the analog signal present at this channel is converted to its digital form. Hence there is time sharing/ time division multiplexing scheme followed by ADC0808 fabricated in the DAS card. The eight channels are scanned in this way at a rate of 100 kHz. Now the DAS card is interfaced with PC through parallel port using EPP (Enhanced Parallel Port) mode of data transfer. There are some handshaking signals which are generated automatically during the data transfer through parallel port using EPP mode, which are shown through some timing diagram in Fig.6 and Fig.7.

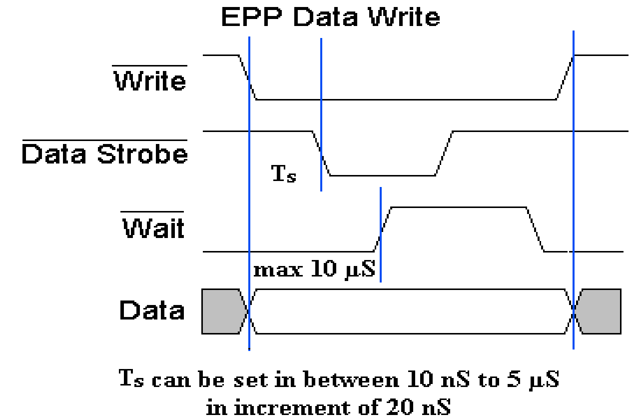


Fig.6: EPP data write cycle

EPP data write cycle shown in Fig.6 is explained below:

Step 1:- Program writes data to EPP data register using the address of the register (Base Addrs. + 4) and data is latched to the register.
Step 2:- nWrite is placed low. (Low indicates write operation on the data bus)
Step 3:- Data is placed now on the data lines 0-7 from EPP data register.
Step 4:- nData Strobe is asserted (activated) if nWait is Low (O.K. to start cycle).
Step 5:- Host waits for Acknowledgment by nWait going high (O.K. to end cycle).
Step 6:- nData Strobe is de-asserted.
Step 7:- The Cycle Ends after reassertion of nWait.

EPP data read cycle shown in Fig.7 is explained below:

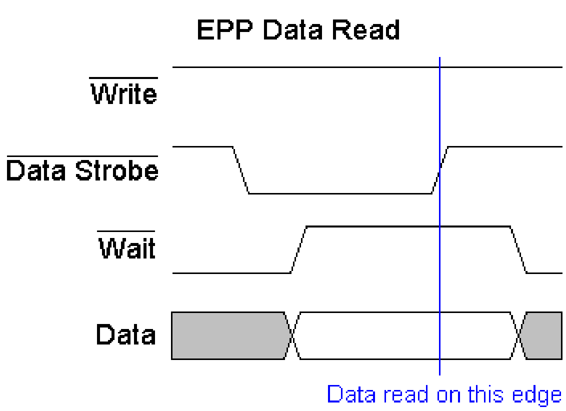


Fig.7: EPP Data read cycle

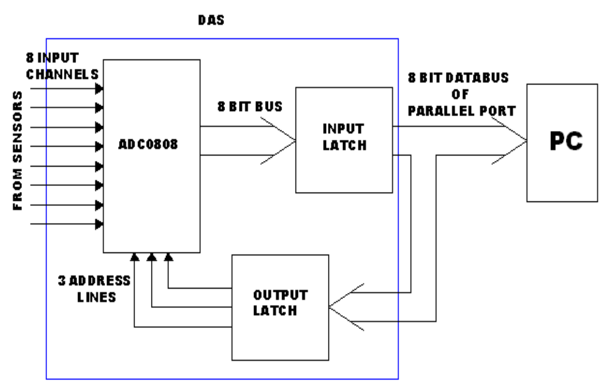
Step 1:- Program reads data from EPP data register using the address of the register (Base Address + 4).
Step 2:- nData Strobe is asserted if nWait is Low (O.K. to start cycle).
Step 3:- Host waits for Acknowledgment by nWait going high.
Step 4:- Data is read from Parallel Port Pins.
Step 5:- nData Strobe is de-asserted.
Step 6:- EPP Data Read Cycle Ends.

Hence all the handshaking signals like (Write)'.
(Datastrobe)', (Wait)' are automatically generated by the PC in EPP mode and one thing is important to notice that when (Write)' = Low,
(Datastrobe)' = Low and (Wait)' = Low, only then the valid data is available in the parallel port. Similarly when (Write)' = High, (Datastrobe)' = Low and (Wait)' transits from Low state to High state, only then data available on the port is read into the PC and stored. Therefore valid data is available for very small interval in the parallel port in case of data write and data read cycles both. So it is required some external hardware circuitry which synchronizes with these handshaking signals and supply as well as receive data to/ and from parallel port of the PC. The internal block diagram of the DAS card designed by us, shown in Fig.8.

2.5 Storage & Monitoring

Now the ambient temperature and moisture of soil measured, is to be displayed on the screen of the PC for monitoring and analysis. Hence software is to develop which will take the equivalent digital value of the measurands from the parallel port, converts them to the correct measured values and will display them on the screen either graphically or digitally. Here the software is developed using C programming language. To make the software user friendly, the software is GUI (Graphical User Interface) based and mouse programmed.

Fig.8: Block diagram of DAS card



There are two parts into the software – first is calibration part, second is real time process part. Calibration part gives the operator to calibrate the measured parameters and to store the calibration results into a database. The calibration part also gives the facility to display the contents of the database to the user. In real time process part, the software collects the measured data from parallel port, goes to a search process into the database to retrieve the physical measured value of a particular physical parameter (temperature or moisture) and show the retrieved physical parameter either digitally or graphically as selected by the user.

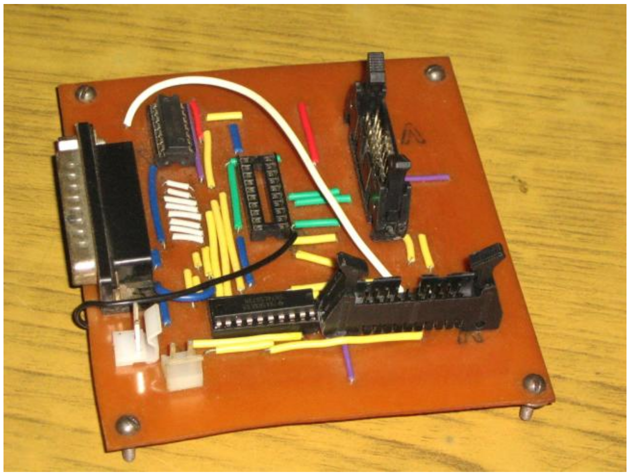


Fig.9: Photograph of DAS card

3. FUTURE SCOPE OF WORK

In this paper, we have presented an open architecture precision agriculture information monitoring system. It is composed of a sensor network and a PC based Information service system. The coverage area of the system is limited due to the wired network created between the sensor cluster and the PC. This problem can be overcome using a wireless network to connect the sensor

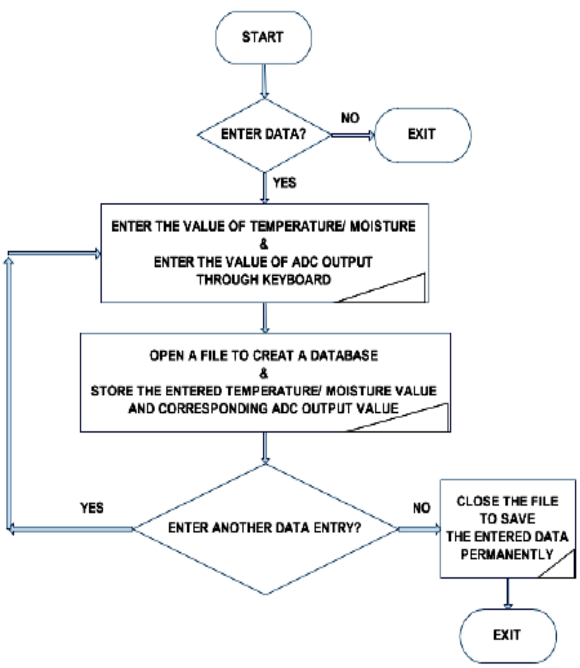


Fig.10: Flowchart of data calibration procedure

clusters and the PC, as well as we can upgrade the system architecture in two tires. Where the low tire of the sensor network a large amount of energy limited sensor clusters will be deployed in the form of a node to receive and transmit necessary information towards a local database system, which is also connected with the central database system placed in a location far away from the field of data collection in order to analyze the collected information for future use. In the higher tire of the network, this central database will be connected with the internet with the help of some powerful GPRS gateway, in order to provide an all time access to the users. In order to prepare the above-mentioned architecture the following things can be taken care of which is mentioned point wise regarding each part of the system,

1. The data-collecting node can be upgraded by adding new climatic and biological sensors.

2. Number of sensors per node can also be increased by upgrading the capacity of the DAS card.

3. With the help of wireless network these nodes can be deployed over a vast range of landscape with out being bothered by the topology of the area.

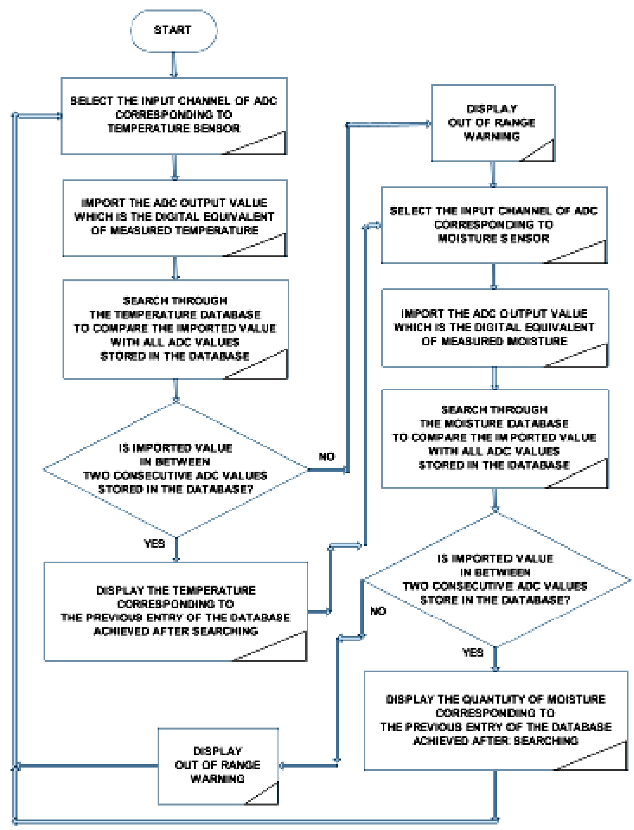


Fig.11: Flowchart of real time display of measured parameters

4. For wireless communication RS-232, based DIGI's X-Bee–PRO 802.15.4 transceiver module having OQPSK based modulation can be used. The operating temperature is –40ºC to 85ºC and the power down current is less than 6 mA. It can transmit data up to 1 mile for outdoors range (LOS) and 100m in indoor range at frequency 2.4 GHz.

5. In order to maintain the power requirement of the various parts of the system solar cells can be introduced which will eliminate the frequent check for the source of power of various parts of the lower tier of the system.

6. An efficient and powerful algorithm should be developed to maintain a systematic scanning process for the local monitoring system and overall synchronization of data transmission and reception for the central database system in order to avoid congestion and data loss.

4. CONCLUSION

Beside the impact of Globalization, major crisis in Indian agriculture are improper land-reforms and lack of applications of technology at large scale. Basically fundamental researches on agriculture are not so developed to invoke 'intermediate technologies' on agricultural field; also the extension service to circulate the necessary information to the farmers is very wretched. That is why the developing nation like India is suffering from utilizing her enormous natural resources that leads to the ultimate crisis to ensure the food security for the entire nation. So till in the 21st century, agricultural sector are neither ready to meet up the complete demands of food for 1.2 crore people of India nor to export for other countries**.** In this context, we have tried in our limited scope to facilitate the agricultural workers to overcome some of their problems.

5. REFERENCES

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