APPLICATION AND ANALYSIS OF SENSORS USED FOR PRECISION AGRICULTURE: A REVIEW

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Abstract: ***In the present era of Internet of Things (IoT), data driven decision making is getting much acceptability in industrial and agricultural sectors. Increase in world population and reduction in resources for agriculture have challenged the conventional farming method to optimize the utilization of resources in a statistical way. Therefore, different field parameters need to be collected and correlated to decide the optimum amount of resource to be applied. Estimation of field parameters are possible by visually comprehending the variation in color gradient or by applying multiple specialized sensors for different parameters at the field. Estimation of physical parameters, field parameters and environmental parameters with required accuracy helps to determine the accurate amount of the resource to be applied. Optimization of resources is the key requirement in the present situation which is not possible without the appropriate sensors. In this paper different types of sensing mechanisms have been discussed with their pros and cons to highlight the potential research challenges in current sensing technology.***

Key words: ***Internet of things, Precision Agriculture, Sensors, Smart Agriculture***

I. INTRODUCTION

In the present era of agriculture 4.0, Internet of things (IoT) has become an indispensable technology to acquire field parameters for analysis and estimation of required resources using data driven techniques. The reliability of conventional farming is gradually vanishing due to its incompetency in reducing resource consumption in a statistical way. In the present day, conventional agriculture has been transforming into precision agriculture to resolve the threat perceived in crop production. The news reported by the Department of Economic and Social Affair, United Nations, has revealed their concern to increase food production by 56% to feed about 10 billion people on earth by 2050 [1-2]. It is a burning issue about the availability of required resources such as area of arable land, irrigation water, required manure etc. to produce such a huge amount of crop.

Therefore researchers have moved on to data driven crop production method which is aimed at high yield with optimum resource utilization. This method is popularly known as precision agriculture in which analysis of atmospheric parameters, physical parameters of crop, chemical characteristics of soil etc., are studied carefully in comparison to traditional farming [3]. Acquisition of environmental and physical parameters is performed by different types of sensors. This data is transferred to a data hub situated at the remote end from the field by the help of wireless communication technology. Analysis of data is done by the machine learning algorithm to provide decisions to the field actuators for optimum resource utilization. In this paper different types of sensors, their working principle and specific application have been discussed to facilitate the selection of sensors by researchers.

II. OVERVIEW OF SENSORS USED IN PRECISION AGRICULTURE

Traditional method of farming is becoming less significant in this era in order to make a data driven approach to resource utilization. This approach gives the farmers a better way to optimize the utilization of resources to produce required yield. Observations and literature reviews show that a lot of parameters need to be analyzed in order to get the resource optimization. Better yield requires better crop health at different stages of growth. Hence, atmospheric parameters like ambient temperature, humidity, wind speed, solar radiation intensity and precipitation need to be observed carefully before applying the resources at different seasons. Again different characteristics of soil e.g. soil moisture, soil temperature, soil nutrients, soil pH level also need to be taken into account before applying the resources as they have a collective effect on crop yield. These aforesaid parameters are measured by the help of sensors that transform the parameters into voltage or current. The obtained value of voltage and currents are converted into mathematical expression to map the voltage or current directly into the measured parameters. The following subsections are dedicated to the overview of sensors used for different purposes in precision agriculture.

2.1 *Measuring parameters for precision agriculture*

Precision agriculture is an agricultural management activity which begins with soil sampling for proper crop to the crop transportation to market. Under this long chain of management activity, several parameters are analyzed to make necessary decisions on utilizing resources. The parameters can be estimated into two ways. These are:

a. Vision based: In this approach, the required parameters are estimated by analyzing the pixels from images and videos of different stages and segments of crop, colors of soil and farm field.
b. sensor based: This approach directly extracts the parameters by implanting sensors in the field and establishing mathematical relations among them.

In this section some of the important parameters and their respective sensors have been discussed.

2.1.1 Mechanical Sensors:

Soil compactness is a physical parameter which is considered as not suitable for farming. Soil compactness is dependent on the physical structure of the soil. Soil compactness is measured as the amount of force exerted by the frontal part of the tool to enter into or cut through the soil. This force is measured by the load cell or strain gauge [4]. The force exerted by soil during the penetration of the tool is measured using a conical rod connected with the load cell. Though the working principle and construction of the sensor is quite simple, there is a high risk of damage of the tool beyond a specified depth of hard compact soil [5].

2.1.2 Acoustic sensors:

Acoustic sensors find its application in indirect measurement of soil moisture content besides its direct applications in the mechanical engineering branch. These sensors produce sweep frequency signals of 50 KHz -100 KHz range that get reflected from any obstacles in front of it. The amount of energy reflected or the attenuation level of the reflected energy in soil helps to determine the moisture content of the soil [6-7]. Acoustic sensors are also used to detect pest in the soil by acquiring the noise level created by the insects [8]. Classification of seed size and shape are also done by inspecting the sound absorption coefficient spectra for the seed parameters [9]. But design complexity and additional hardware for maintaining accuracy makes these sensors costly and unsuitable for poor farmers [10].

2.1.3 Electrochemical sensors

Soil nutrients are the most important ingredient for plant growth. They are obtained from organic matter or from chemical fertilizers. Nitrogen, phosphorus and potassium are the key ingredients of these fertilizers which makes the soil fertile. For proper growth of the plants, precise quantity of the ingredient is necessary. To detect the amount of nitrogen precisely, near infrared reflectance (NIR) based sensors are used. Laser-Induced Graphene (LIG) based electrodes are another type of ion sensitive electrochemical sensor that senses plant available nitrogen [11]. Chemical Field Effect Transistors (ChemFET) are semiconductor devices which replace the Gate terminal of the Field Effect Transistor with an intrinsic electrolyte layer covered with ion sensitive membrane. With this layer, the transistor is able to detect the pH level of the soil [12]. But these sensors suffer from erosion of the Gate terminal and hence are not extensively used to detect the nutrients.

2.1.4 Optical Sensors

Optical sensors are good to identify different parameters for crop growth in a large area of a farm field. The detection of necessary parameters is done based on color gradient variation of crop. Color gradient variation of crops indirectly indicates the presence of nutrients and moisture in soil. Red, Green, Blue (RGB) and Near Infrared Spectroscopy (NIRS) sensors are mostly used to identify the nutrient level in soil and health issues in plants. An Unmanned Aerial Vehicle (UAV), equipped with a camera having these optical sensors, is used to inspect the field from above [13]. Optical sensors are therefore useful for mapping the crop production using machine vision. But the result may not be satisfactory in bad weather conditions, foggy weather, pest attacks because at that time the color gradient variation is affected from the normal variations [14].

2.1.5 Ultrasonic Ranging Sensor

Ultrasonic distance measurement sensors find its application in estimating the rate of growth of corn plants. As these sensors are able to detect the proximity, therefore they are used to measure height of the plants to estimate growth [15]. These sensors are low cost, rugged and can be interfaced easily with commercial low cost development boards. But these sensors need to be installed perpendicular to the target to obtain ultrasound reflection which makes them unsuitable for use in gardens. But

2.1.6 Field Programmable Gate Array based Sensors

In precision agriculture, the accuracy of measured parameters is very essential for precise data analysis and optimize the resource utilization. Field Programmable Gate Arrays (FPGA) boards are nowadays used in precision agriculture due to their accuracy. In these boards, the data obtained from sensors are processed using finite impulse response filters. This method increases accuracy of the received signal than commercial low cost boards [17]. FPGA boards are equipped with dynamic configuration facilities that helps them to interface heterogeneous sensors which have different voltage and current levels. Also these boards facilitate changing the system configuration at runtime. FPGA platforms uses IEEE 802.15.4 communication standards and IEEE 1451.5 standard to utilize Transducer Electronic Datasheet (TEDS) of sensors for automatic calibration [18]. FPGA platforms are costly and power hungry [19]. Hence these boards are not affordable for poor farmers.

III. COMPARATIVE ANALYSIS OF THE SENSORS

In this section, a comparative analysis of the sensors have been presented. An elaborate description of the sensors have already been discussed in the previous section. The analysis has been done to facilitate the researchers to select the correct sensors by considering the sensing mechanism, application area, limitation and advantages of sensors.

Name of Sensor	Function of sensor	Advantages	Limitations	Application Area
Mechanical Sensor	penetration force measurement inside soil	Cost effective, rugged, have better accuracy, easily integrated with tractors	Need regular maintenance, limited depth of penetration in hard soil (approx 30cm)	Testing of soil compactness
Acoustic Sensor	Measuring ultrasonic signal attenuation reflected from soil.	No soil contamination	Costly, Increased hardware complexity, better accuracy achieved with additional transducer	Detection of foliage, soil moisture and soil compactness
Electrochemical Sensor	Measuring content of nitrogen, phosphorus and potassium content in soil	Good sensitivity, simple manufacturing, cost effective, easy interfacing	Soil erosion occurs, less life time	measurement of nutrient level of soil (Nitrogen, Phosphorus, Potassium)
Optical Sensors	To identify colour gradient variation	Non-destructive testing of soil	Affected in adverse weather condition, fog, pest attack	Estimation of Nitrogen requirement in different sections of field
Ultrasonic Ranging sensor	To measure distance using ultrasonic sound reflection	Rugged, low cost	sensor has to be placed at a higher height than crop, measurement accuracy varies with tilting of sensor	Used for crop growth measurement in terms of height
Field Programmable Gate array Based sensors	dynamic configuration of heterogeneous sensor assembly	Dynamic configuration of sensor at runtime, auto calibration	costly, power hungry	All types of sensing activity using heterogeneous sensors

IV. CONCLUSION

The scarcity of useful resources for agriculture has thrown a challenge to feed a huge population by producing crops with optimum amount of resources. As a result, a data driven approach has been preferred in next generation farming to reduce the wastage of limited resources. Gathering field data and performing analysis using suitable algorithms to determine appropriate quantities of the applicable resource is getting the first priority. To do that, numerous field parameters are collected by implanting sensors in the field at every corner according to the geometry of the field. Vision based approaches are considered better when large fields need to be surveyed but sensor based approaches are suitable for small farm fields. In this paper, a thorough discussion about different types of field sensor presently in use, has been done. The comparative analysis of different types of sensors have been discussed to facilitate the choice of sensor by farmers and researchers as per the application. In future, attempts will be made to discuss the subsequent segments of precision agriculture to create a big picture of the future aspects of precision farming.

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