Precision agriculture for small to medium size farmers - An IoT approach

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***Abstract*—Word population has almost doubled during the last century increasing dramatically the need for food to support a population over 7 billion persons. According to FAO, by 2050, the agricultural production will have to increase by 70%. Plants growth depends on several factors such as nutrients (NPK), soil characteristics, soil Ph, soil moisture, temperature, weather, and light. To manage all the required information and the complexity of plants growth a system, based on IoT technology, able to measure, analyze, and act is needed. IoT is a solution for precision agriculture.A system for precision agriculture, that will be distributed in the field, far from energy and communication sources needs to be low power and able to process the received information and just sending the most relevant information to the cloud for further statistical analysis. This system will be able to measure the most important parameters for plant growth through a set of sensors and act to fix some of those parameters through actuators when needed as well.**

***Index Terms*—IoT, sensors, actuators, SoC, Precision Agriculture**

I. Introduction

World population has increased from 1.65 billion in 1900 to 7.4 billions today. The pace of this increase is not changing and Earth is estimated to have 11.2 billions by the end of this century. In contrast with that growth, the arable land is decreasing from 0.5 Ha per person in 1960 to 0.2 Ha per person in 2020. The world will not have enough food to cover the needs of all the inhabitants without any changing the way we do agriculture today.

Crop productivity is being affected by global warning as well, especially in tropical regions. Global warning is also affecting the availability of water to irrigate the crops, so the agricultural production using traditional methods is decreasing, which is not only impacting the availability of food but also the economy of under developed countries which depends on agriculture. For instance, the percentage of agricultural exportation's of South American countries is over 15% of their exportation while the percentage of agricultural exportation of the world is 2.9%.

To growth a plant it is needed to plant the seed, directly in the soil or in a seedbed, transplant it if needed and irrigate. After a few weeks or months, anyone can eat what was planted. Unfortunately, many other physical parameters impact plant growth. Fig. 1 depicts the most relevant parameters.

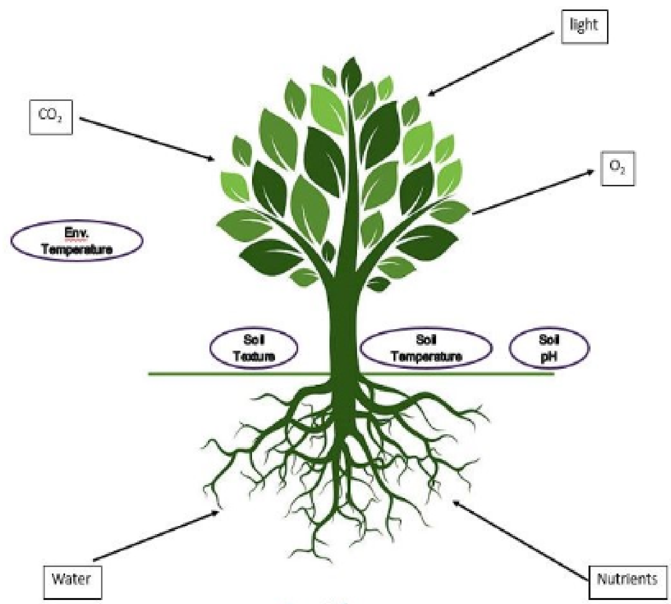

Fig. 1. Plant Growth Physical Parameters.

The paper presents the system we are working on, based on IoT and Artificial Intelligence techniques, to allow small and medium farmers to introduce technology in their farms and to improve the yield of the soil. The first section presents the need for precision agriculture as well as a summarized description of the state of the art. The second section presents the main parameters needed to improve the yield of the soil and how we are measuring them. In this section we present all the sensors we are considering as well as the results we are getting. We also present the threshold values we are considering for each parameter. An overview of the possible actions per parameter is also presented. The third section presents the prototype, based on the ARC development system, as well as the methodology we already defined to implement an SoC from the prototype. At the end we present some conclusions and next steps for this work.

II. State of the Art

Precision Agriculture is an agricultural management concept based on monitoring and responding to inter and intra-field

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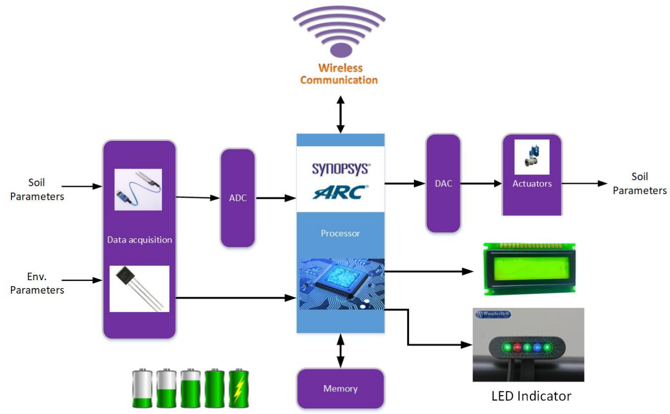

Fig. 2. Proposed system

variability in plants and soil [1].

IoT is the core of Precision Agriculture (PrecisAgri). It acts as a sensor of main parameters that influence growth. It has the capacity to increase and optimize crop throughput by using appropriate mathematical models. This control is not limited to the plant itself but also to its environment. It can also be used to optimize crop irrigation and reduce the consumption of water which is a critical and heavily used element in agriculture.

In nations where agriculture plays a major role in the economy, such as India, China, and Algeria, research on IoT and agriculture has been of importance. Virtually all publications regarding the subject have come out of those countries. Business Insider reports that 75 million agricultural IoT devices will be shipped worldwide by 2020. IoT will be the system that address agricultural challenges based on its information collected in addition to GPS, drones, and sensors.

Romit Atta published an article in August 2017 [2] "At the turn of the century, none of the 525 million farms across the world had sensor technology. Cut to 2025, and we will witness more than 620 million sensors being used " [...] "2 billion smart agro-sensors expected to be in active use by 2050". Finally, "Between 2017 and 2022, the agricultural IoT market is set to expand at a mighty impressive Compound Annual Growth Rate (CAGR) of around 16% - 17%".

Several applications based on IoT have been developed mostly in countries where agriculture plays a key role in the economy. The systems described in literature perform only data processing in the cloud with no edge processing. That implies more energy consumption, unsuitable for systems running on a limited battery power. Moreover, those systems use off-the-shelf platforms, e.g. Arduino and Raspberry. The usage of these platforms shows they are still at a prototyping stage and that there has not been any production so far.

Some of current system are presented in the list below

- Shareef and Viswanathan present an agricultural monitoring system based on sensors [3].
- Jaiganesh, Gunaseelan, and Ellappan present an IoT system to improve food and farming technology [4].
- Shenoy and Pingle present several agricultural issues on how IoT can provide data to provide solutions to the issues they are analyzing [5].
- Fan TongKe states that agricultural modernization is key for China [6].
- Fu Bing made researched IoT for agriculture based on three-layer architecture [7].
- Parameswaran and Sivaprasath have developed an Arduino based irrigation system using IoT [8].
- Khelifa et al. propose a smart irrigation system using IoT [9]

III. Improving the Soil Yield

A first analysis shows that the parameters that influence a plant growth could be categorized as soil parameters and environment parameters. Among the soil parameters we have moisture, nutrients, pH, temperature, and texture. Environment parameters are light, temperature, and weather.

Another important classification is the one that divided the relevant parameters in the ones we can automatically act if they are out of the defined range and the ones we can just inform that they are out of the desired range.

So far, we have concluded that the parameters the proposed system can automatically act are soil moisture, soil nutrients and the soil pH. Other parameters act as indicators that will help to know how to act on the parameters that can be changed automatically.

The proposed system is shown in Fig. 2.

The system is composed by a processor, a set of sensor and actuators, a display to provide relevant information, LEDs to provide visual information, batteries and a communication module.

IV. Proposed System to Supervise the Plant Growth

A. Soil Moisture

Soil is composed by 50% of minerals and organic particles and 50% of porous space occupied by air and water. Plant behavior is directly affected by water condition of the soil

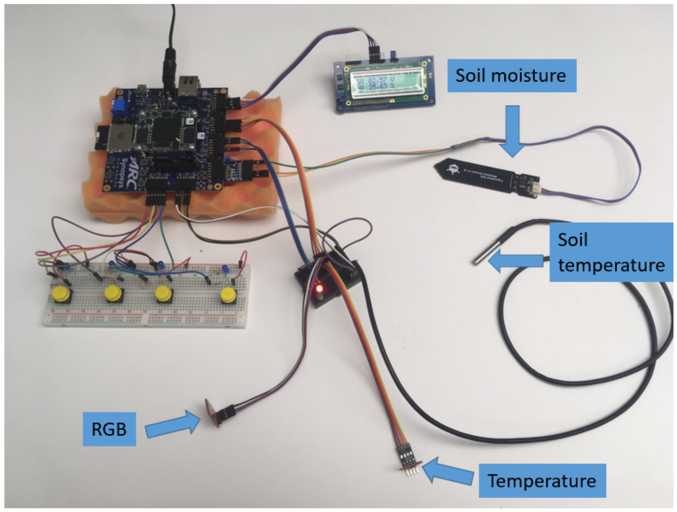

Fig. 3. Prototype

which is described from the content and energy of the water in the soil. Water in the soil can be classified into 3 categories: gravitational, non available for plants, and available for plants [10].

Soil moisture will be measured in real time using a sensor that can be easily found in the market. The system will compare the sensed value with a threshold that is plant dependent and will launch irrigation if needed. Irrigation cannot be done at any time of the day, the system will also take in account soil temperature, air temperature, and the time of the day to launch the irrigation.

So far we have tested resistive (FC-28) and capacitive (SEN0193) sensors. Results are similar, however we have found that resistive sensors are less stable than capacitive ones, despite the fact that they are cheaper.

B. Soil Nutrients

16 chemical elements are known to be important to a plants growth and survival. Among those nutrients we find the minerals and the non minerals. The most important non minerals are Hydrogen (H), Oxygen (O) and Carbon (C). Through photosynthesis (using sun light as energy) the plant converts CO_2 and H_2O into starches and sugars. There are 3 main minerals nutrients: Nitrogen (N), Phosphorous (P) and Potassium (K), known as NPK. Together, they are part of the photosynthesis and help on the rapid growth and build proteins. Nutrients are often found in the soil but they can be added thanks to fertilizers. Excessive or lacking of fertilizer use has a significant effect to crop yield [11].

Nutrients measurement will be done through the reflection characteristics of the NPK based on Lambert-Beers Law. The absorption is given by

$$A = -log_{10}\frac{I_1}{I_0}$$

where I_1 is transmitted light and I_0 is incident light [12].

Our proposed system will compare the measured value for each nutrient with the recommended value for the specific plant that is being considered. If the value is incorrect, the system will use different methodologies to reduce or increase the values of each nutrient.

We have built a prototype using the ISL29125 light sensor from Renesas. At the same time we have sent samples of soil to a certified lab, so we will be able to calibrate our own sensor.

C. Soil pH

Soil pH refers to the acidity or alkalinity of the soil. It measures the concentration of free hydrogen ions (H+) in the soil. pH range is from 0 to 14 with 7 as neutral. The pH is one of the most important soil properties that affects the availability of nutrients in relation with plant roots and microbial activity. NPK tend to be less available in soil with low pH. Soil pH can also affects soil bacteria, nutrient leaching, toxic elements and soil structure [13].

We have started to test the Atlas Scientific pH Probe that is able to measure in situ the pH of the soil. We do not have any specific result at the time this paper is written.

D. Soil Temperature

Soil is a major storage for heat. It is a reservoir of energy during the day and a source of heat to the surface at night. Soil temperature governs physical processes, chemical processes and biological processes. The amount of received radiation affects soil temperature and some biological processes such as seed germination, seedling emergence, plant root growth and nutrient availability [14].

Soil temperature will be measured using an appropriate temperature sensor (e.g. DS18B20) that can be found in the market. The system will not be able to act if the soil temperature is out of range, however it will generate an alarm. Prediction of soil temperature and its consequences on crop growth, using machine learning are of interest for the farmer.

E. Soil Texture

It corresponds to the amount of sand, silt, clay and organic matter. The texture affects how good nutrients and water are retained in the soil. As water drain from sandy soils, it carries nutrients along with it. This is called leaching. When nutrients leach into the soil, they are not available for plants. Clay and organic soils holds nutrients and water much better than sandy soils. An ideal soil contains equivalent portion of sand, silt, clay, and organic matter [15].

Soil texture is supposed to do not change too often so no measurement will be done by the system. The system will use the soil texture, coming from an analysis in a laboratory, as a relevant parameter.

F. Environment Temperature

The rate of plant growth and development is dependent upon the temperature surrounding the plant and each species has a specific temperature range represented by a minimum, maximum and optimum. Studies have shown that increasing the average temperature from 16.3C to 21.1C increased early season growth and reduced crop duration. This effectively reduced total yield by 17%. Pollination is one of the most sensitive phenological stages to temperature extremes across all species and during this development stage temperatures extremes would greatly affect productivity [16]. Responses to temperature is different among species and through their life cycle.

This parameter can be measured through a temperature sensor that can be bought in the market (e.g. SI7021) or be acquired from a weather station connected to the system. The system cannot act if out of range, however an alarm will be generated if needed.

G. Weather

Data will be acquired from an external weather station. The values will be an input to the system to be used in relevant calculations or to generate alarms to the farmer.

H. Light

Plants use light, water, and carbon dioxide (CO_2) to produce sugar, which is converted to ATP (Adenosine 5'-triphosphate) by cellular respiration. This conversion is made through photosynthesis [17].

Different aspects of the light are important for plan growth [18]: Light quantity, light quality, and light duration.

As our work is for outdoor plants, we will not measure the light as we are not able to influence on it.

A summary of these parameters and its impact is presented in Table

TABLE I
PARAMETER ACTION

Parameter	Action
Soil Moisture	Automatic
Soil Nutrient	Automatic/Alarm
Soil Ph	Automatic/Alarm
Soil temperature	Alarm
Soil texture	Input [a]
Environment temperature	Alarm
Weather	Input [a]
Light	No action [b]

[a]Used as input of the system.
[b]No action taken.

V. Prototype

We are currently working with a DesignWare ARC EM Starter Kit for the ARC EM family of embedded processor cores (Synopsys). We are specifically using the DesignWare ARC EM7D processor, which is based on the ARCv2DSP Instruction Set Architecture. The starter kit provides also several interfaces allowing us to connect the sensors we already presented and to develop the software we are using to measure the different interesting parameters. This platform will also allow us to drive the actuators we will consider for the parameters we are planning to modify automatically.

A picture of current prototype is presented in Fig.3

For the wireless communication part we are implementing a LoRa [20] interface.

An important part of the software is already developed and we are able to read almost all presented sensors. As we have not yet defined the actuators we are planning to use in the final system, we have connected a display to indicate the value of the parameter and a set of LEDs to show if we are over (red) or under (green) the defined threshold.

So far we have only made laboratory test and we are now preparing a prototype that could be installed in the field to start taking real values.

VI. Perspectives

The following tasks are already defined as next steps for this research work

- Define measurement frequency, i.e. how often each parameter has to be measured.
- Analyze system power to be able to define the battery we are going to use in the field and the need for final chip.
- Define SoC architecture and work on the SoC implementation.

VII. Conclusion

2 important effects related to population growth which are respectively, cities being bigger and decreasing arable surface. Improving the soil yield with IoT is a new way to feed this population growth. Our proposed solution integrates IoT to monitor precisely agriculture. We have almost finish the development of the first prototype and we are going to start the tests on the field. The subsequent manufacture of a SoC will demonstrate on site how farmers can be helped to improve soil yield.

References

[1] Sophocleous Marios and Julius Georgiou, "Precision Agriculture: Challenges in Sensors and Electronics for real-time Soil and Plant Monitoring", 2017 IEEE Biomedical Circuits and Systems Conference (BioCAS), October 2017

[2] Romit Atta, Farming 2.0: How does IoT help agricultural domain, August 2017.

[3] Mahammad Shareef Mekala and Dr P. Viswanathan, A novel technology for smart agriculture based on IoT with cloud computing, I-SMAC, 2017.

[4] Jaiganesh S., Gunaseelan K., and Ellappan V., IoT agriculture to improve food and farming technology, ICEDSS, 2017.

[5] Jeetendra Shenoy and prof. Yogesh Pingle, IoT in agriculture, 2016 International conference on Computing for Sustainable Global Development.

[6] Fan TongKe, Smart agriculture based on cloud computing and IoT, Journal of Convergence Information Technology (JCIT), Volume 8, Number 2, January 2013.

[7] Fu Bing, The research of IoT of agriculture based on three layers architecture, 2016 2nd International Conference on Cloud Computing and Internet of Things (CCIOT).

[8] Parameswaran, K. Sivaprasath, Arduino based smart drip irrigationstem using Internet of things, International Journal of Engineering Science and Computing (IJESC), volume 6, issue N5, May 20169

[9] Benhamed Khelifa, Douli Amel, Bouzekri Amel, Chabane Mohamed, and Benahmed Tarek, Smart irrigation using internet of things, Fourth international conference on future generation communication technologies (FGCT), 2015

[10] Paola Silva, Herman Silva, Marco Garrido, and Edmundo Acevedo, Manual de Estudio y Ejercicios Relacionados con el Contenido de Agua en el Suelo y su Uso por los Cultivos, Universidad de Chile, Santiago, 2015

[11] John Carlo Puno, Edwin Sybingco, Elmer Dadios, Ira valenzuela, and Joel Cuello, Determination of Soil Nutrients and pH level using Image Processing and Artificial Neural Network, in 9th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM), 2017.

[12] D.A. Skoog, D.M. West, F.J. Holler, and S.R. Crouch, Fundamentals of Analytical Chemistry, Cengage Learning, 2013.

[13] W.H. Allaway, pH, Soil Acidity, and Plant Growth, Yearbook of Agriculture 1957, pp. 67-71.

[14] Jerry L. Hatfield, John H. Prueger, "Temeperature extremes: Effect on Plant Growth and development," Weather and Climate Extremes, Vols. 10, Part A, pp. 4-10, 2015.

[15] Allan Hewitt, Soil Properties for Plant Growth, Landcare Research Sciences Series N 26, 2004

[16] M. Onwuka B, Effects of Soil Temperature on Some Soil Properties and Plant Growth, Adv. Plants Agric Res 8, 2018.

[17] C. Darwin, in The power in Movement in Plants, 1880, p. 205 and 217

[18] Jose Chen Lopez, Influence of Light on Crop Growth, Pro-Mix Greenhouse Growing, January 2018

[19] Synopsys ARC EM Starter Kit \\https://www.synopsys.com/dw/ipdir.php?ds=arc_em_starter_kit

[20] Guillaume Ferré, Audrey Giremus, LoRa Physical Layer Principle and Performance Analysis, ICECS, December 2019