Monitoring of soil and atmospheric sensors with internet of things (IoT) applied in precision Agriculture

Monitorização de sensores do solo e atmosféricos com internet das coisas (IoT) aplicados em agricultura de precisão

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Alessandra Dutra Coelho
Engenharia Eletrônica
Instituição: Instituto Mauá de Tecnologia
Endereço: Praça Mauá, 1 - Mauá, São Caetano do Sul - SP, CEP: 09580-900
E-mail: alessandra.coelho@maua.br

Bruno Guilherme Dias
Engenharia Elétrica
Instituição: Instituto Mauá de Tecnologia
Endereço: Praça Mauá, 1 - Mauá, São Caetano do Sul - SP, CEP: 09580-900
E-mail: bruno.guilhermeld@gmail.com

Wânderson de Oliveira Assis
Engenharia Eletrônica
Instituição: Instituto Mauá de Tecnologia
Endereço: Praça Mauá, 1 - Mauá, São Caetano do Sul - SP, CEP: 09580-900
E-mail: wanderson.assis@maua.br

Fernando de Almeida Martins
Instituição: Centro de Pesquisas do Instituto Mauá de Tecnologia
Endereço: Praça Mauá, 1 - Mauá, São Caetano do Sul - SP, CEP: 09580-900
E-mail: fernando.martins@maua.br

Rogério Cassares Pires
Instituição: Centro de Pesquisas do Instituto Mauá de Tecnologia
Endereço: Praça Mauá, 1 - Mauá, São Caetano do Sul - SP, CEP: 09580-900
E-mail: rogerio.cassares@maua.br

Arthur da Silva Kuke
Elève-Ingénieur Spécialisé em Microélectronique Informatique et Nouvelles Technologies
Ecole Nationale Supérieure de Mines de Saint-Etienne - France

ABSTRACT
This work consists in the development of a system for data acquisition of parameters in an agricultural application. For this, the system includes the monitoring of soil moisture and atmospheric sensors (temperature and relative humidity), in order to provide subsidies to farmers in decision-making, aiming at a future implementation of an automated irrigation system, with minimization of

waste of water resources. Data acquisition is carried out by means of sensors connected to a microcontrolled system, and the signals are transmitted through a radio frequency module using LoRaWan^{TM} protocol. Data is received at a gateway and made available in the cloud, applying Internet of Things (IoT) concepts, and can be monitored in real time in an academic interface. Additionally, the data can also be monitored through a simplified interface accessible through an app developed specifically for the application.

Keywords: precision agriculture, irrigation system, internet of things, sensors.

RESUMO
Este trabalho consiste no desenvolvimento de um sistema de aquisição de dados de parâmetros numa aplicação agrícola. Para tal, o sistema inclui o monitoramento da umidade do solo e sensores atmosféricos (temperatura e umidade relativa), a fim de fornecer subsídios aos agricultores na tomada de decisões, tendo em vista uma futura implementação de um sistema de irrigação automatizado, com minimização do desperdício de recursos hídricos. A aquisição de dados é realizada por meio de sensores ligados a um sistema microcontrolado, e os sinais são transmitidos através de um módulo de radiofrequência utilizando o protocolo LoRaWan^{TM}. Os dados são recebidos num gateway e disponibilizados na nuvem, aplicando conceitos de Internet das Coisas (IoT), e podem ser monitorados em tempo real numa interface acadêmica. Adicionalmente, os dados também podem ser monitorados através de uma interface simplificada acessível por meio de um aplicativo desenvolvido especificamente para a aplicação.

Palavras-chave: agricultura de precisão, sistema de irrigação, internet das coisas, sensores.

1 INTRODUCTION

Currently, many efforts have been made in the study and development of new technologies that provide the increase in agricultural production, without neglecting the quality of food and the sustainable use of natural resources. In this sense, many researches and projects have been carried out with the use of Internet of Things concepts focused on precision agriculture [1, 2].

The “Internet of Things” (IoT) is a highly promising family of technologies, which is capable of offering many solutions towards the modernization of agriculture [3, 4, 5].

The term Internet of Things (IoT) refers to using of several technologies for monitoring of physical objects, vehicles, buildings and several other things from real world through remote devices. The IoT includes embedded technology and sensors, in order to connect them in a network allowing to collect and transmit data and monitoring in real time, generally with data being stored in the cloud.

The dissemination of the potential of Internet of Things technologies among farmers, but also in the large manufacturers of equipment used in agriculture, has aroused the interest of this sector in the application of available resources for the automation of properties and the machines used.

For farmers, the benefits include minimizing operating costs and saving the excessive use of natural resources. After all, even with technological advances, waste still exists and is significant. As a result, several projects have been carried out, in order to optimize the use of resources (such as water, fertilizers and nutrients) and ensure greater control in irrigation systems [6, 7].

According to the Water Resources Situation in Brazil (CRHB - Conjuntura dos Recursos Hídricos no Brasil) report of the National Water Agency (ANA - Agência Nacional de Águas), agricultural activity is responsible for the consumption of 72% of water resources, as one of the most important aspects in agriculture for the good development of plants is the amount of water in the soil, to ensure adequate moisture conditions, depending on the type of planting [8].

In order to optimize irrigation, monitoring of sensor signals is essential for guarantee the control of soil variables [9, 10].

Some works presents as differentials the possibility of transmitting data using LoRa technology, allowing to monitor over considerable distances and with reduced energy consumption [11, 12].

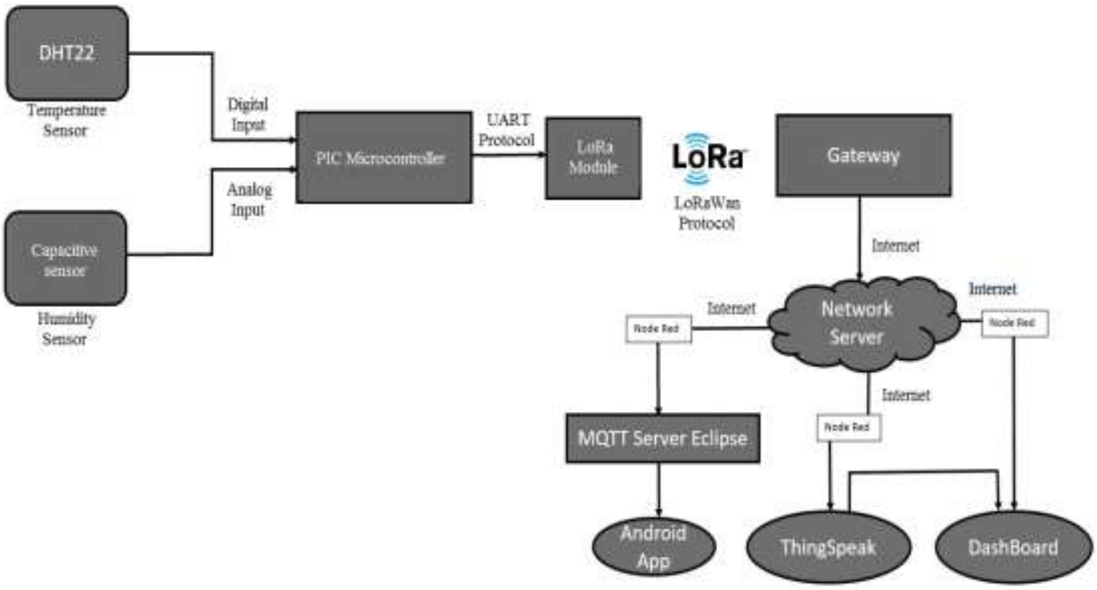
Within this context, this work presents a solution for monitoring the variables soil moisture, ambient temperature and relative humidity, with the data being transmitted using the LoRaWan™ protocol, being stored in real time in a database, allowing the historical register of the data, and includes an IoT platform as well as an app with access using mobile devices.

2 IoT PROJECT HARDWARE

In order to monitor the sensors, the system hardware was developed as shown in the block diagram at Fig. 1, and include the following elements:

- DHT22 - temperature and humidity sensor that allows measurements from -40 ° C to +80 ° C with an accuracy of ± 0.5 ° C, in addition to a relative humidity of 0 to 100%, with an accuracy of ± 2%; consumes maximum current of 2.5 mA during use and 100 to 150 μA when in standby mode; it is a commercial sensor consisting of a capacitive humidity sensor and a thermistor to detect temperature variations;

Fig 1. Block diagram of the monitoring system for signs of soil moisture, ambient temperature and relative humidity – Hardware and Software.



- capacitive sensor for measuring soil moisture (developed at the Research Center of the Institute Mauá de Tecnologia);
- PIC microcontroller 24FJ128GA36, which following features specifications: 16-bit flash microcontroller, 32 MHz operation, up to 16 channel 10-bit Analog to Digital Converter (A/D); UART, SPI and I2C modules; etc.;
- LoRa RN2903 radio frequency communication module, which is a chip developed by the LoRa Alliance allowing wireless communication with LPWAN (Low Power Wide Area Network), which allows communication with ranges of the order of 3 to 4 km in urban area, and up to 15 km in the open field, with the advantage of relatively low power consumer (of the order of 100 mW); the chip uses CSS (Chirp Spread Spectrum) modulation, which considers a frequency increase or decrease technique over time, making it more efficient and resistant to interference; however, it is not suitable for transmitting voice or video signals or browsing the Internet, being suitable for transmitting only data, even so, at not very high sampling frequencies; the chip incorporates the LoRaWAN^{TM} protocol, which allows the implementation of additional functionalities and ensures operation with interoperability and communication with the gateways available on the market, in addition to including data security (encryption) and algorithms that guarantee the quality of communication;
- Li-ion battery with micro USB cable charging system;

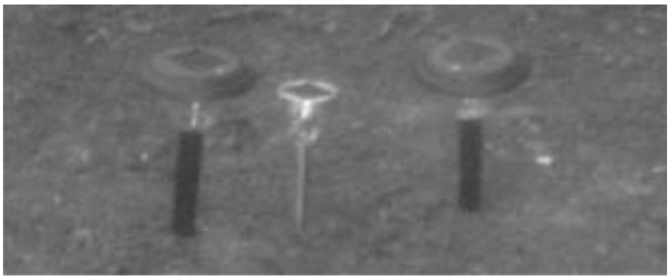
- gateways, are basically devices responsible for concentrating the signals received from all end-points (such as the signals from sensors, for example) and forwarding them to the internet; in theory, a single gate is capable of receiving data from thousands of devices, as long as they are in its coverage area; in this case, a developed gateway installed at the institution itself was used.

The combination of the PIC microcontroller, battery and the LoRa RN2903 module resulted in the development of a board (Fig. 2), produced by engineers who participate in this project, and which is currently marketed by a company.

Fig. 2. End-node Open Source

All sensors and the end-node plate in Fig. 2 were inserted inside luminaires and made available on the ground to allow the tests to be carried out, as illustrated in Fig. 3.

Fig.3. Sensors Fixed to the Ground



3 IoT PROJECT SOFTWARE

The data collected by the sensors and sent by the LoRaWAN^{TM} protocol are received by the gateway and saved on a server of the institution called "Smart Campus Mauá" (Fig. 4). These data are transmitted in the Message Queuing Telemetry Transport

(MQTT) format, a protocol for transmitting messages to applications and / or to mobile devices using the publisher and subscriber system.

The information sent to the Network Server, which contains an MQTT broker responsible for managing the publications and subscriptions of the protocol, can be viewed on the dashboard of the Smart Campus Mauá website (https://smartcampus.maua.br/dash/). The dashboard of the Smart Campus website serves as an information panel to show all the data that arrives at the Mauá gateway and is being stored on the Network Server.

From this point on, the data is made available both to the ThingSpeak website and to a public server (mqtt.eclipse.org), using a topic system to organize this information. This part of the process used Node-RED, a tool aimed at applications related to IoT that uses a graphical approach in an open source environment, making connections between blocks that have predefined code to perform tasks.

In ThingSpeak, data is plotted simultaneously in a public viewing area. Four graphs were created, one for soil moisture, one for ambient relative humidity, one for ambient temperature and one for battery status. These points are plotted and saved to enable any further analysis.

In order to incorporate more functionality into the application, in the next step, an app with MQTT data reader was used in order to produce a personalized and user-friendly dashboard. The investigated applications were: MQTT Dash (IoT Smart Home); MQTT Dashboard - IoT and Node-RED controller; IoT MQTT Dashboard; IoT MQTT Panel.

These applications work as follows: the data that is on the public server (mqtt.eclipse.org) is accessed by the application through a topic system so you can select and collect only the desired data within the public server. In this way, it is possible to separate the information and create the desired dashboard in the form of an application. The data path can be understood at Fig. 1.

4 CALIBRATION OF SOIL MOISTURE SENSOR

As previously described, the project includes the use of a relative humidity and ambient temperature sensor, DHT 22, which is a commercial sensor. However, the capacitive sensors used to measure soil moisture were developed exclusively for the project and therefore need a calibration so that the data produced is reliable and really represents the variation in humidity. In this sense, a complementary project was used in order to calibrate the sensor, with a second commercial sensor, so that the measured values were coherent and coincident.

In this case, the commercial sensor of Fig. 5 was used, which consists of a hygrometer (including comparator LM303), which presents a variation in the resistance measured at its terminals as a function of humidity. This sensor was connected to an Arduino Uno board to allow measuring the humidity values, which will be used to calibrate the new capacitive sensor.

In the capacitive sensor, after the collected data goes through a coding and decoding process in Node-RED, as presented at Fig. 6. The moisture sensor values are expressed in hexadecimal on the dashboard. To perform the calibration, it is necessary to make an interpolation of the sensor values.

The sensors were exposed to air and immersed in water to obtain a reading from 0% to 100%. Then both were placed close to the ground in order to obtain the same reading, the capacitive generating values in hexadecimal and the hygrometer sensor generating values in percentage.

Fig.4. Smart Campus Mauá page showing the signals measured in the ambient temperature and humidity sensor (DET-04) and soil moisture (DET-04, DET-34 and DET-35).

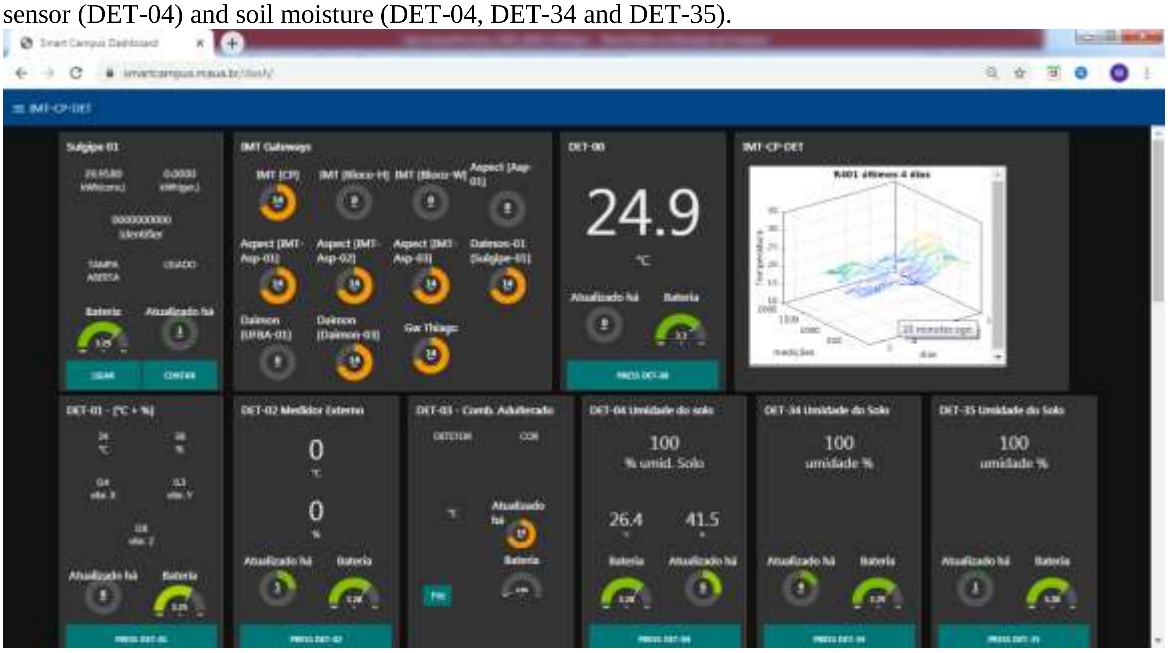
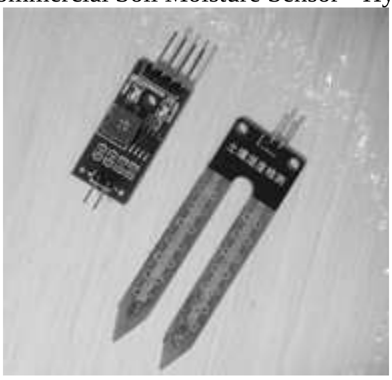


Fig. 5. Commercial Soil Moisture Sensor - Hygrometer



These values were plotted using Microsoft Excel and interpolated, in order to obtain a graph. The hexadecimal values were converted to decimal and using these data an average line of the collected points was created.

5 RESULTS AND DISCUSSION

The planned system hardware was developed and the sensor signals were made available on the Smart Campus platform, as shown in Fig. 4.

From the values collected with the two soil moisture sensors (capacitive sensor and the commercial hygrometer sensor), it was possible to build Table 1 and thus collect data from some measurements, obtaining the graph at Fig. 7.

With this information, it was possible to obtain the load line of the capacitive sensor and thus calibrate it. The linear line that passes through the average of the points is -0.0264x + 114.31. This equation has been inserted in Node-RED (Fig. 6), so that the data available on the dashboard already appear in percentage.

TABLE I. MEASURED SENSORS VALUES

Capacitive Sensor (Hexadecimal values)	Capacitive Sensor (Decimal values)	Relative Humidity (Hygrometer) (%)
0eec	3820	0
0a05	2565	59
0a76	2678	54
0d12	3346	12
0d0e	3342	13
0cfe	3326	25
0cfa	3322	39
0bed	3053	51
207	519	98
293	659	94
179	377	100

After analysing the applications listed in the previous topic, it was determined that the best solution for develop the IoT app was the IoT MQTT Panel, because it has more tools and is better structured compared to others such as the MQTT Dash (IoT Smart Home) that still is under development. Thus, the result obtained can be seen at Fig. 8.

The layout of the dashboard generated by Node-and the graphics generated by ThingSpeak are shown at Fig. 9 and Fig. 10.

Fig. 6. Monitoring algorithm for soil moisture sensor in Node-RED, with equation for calibration

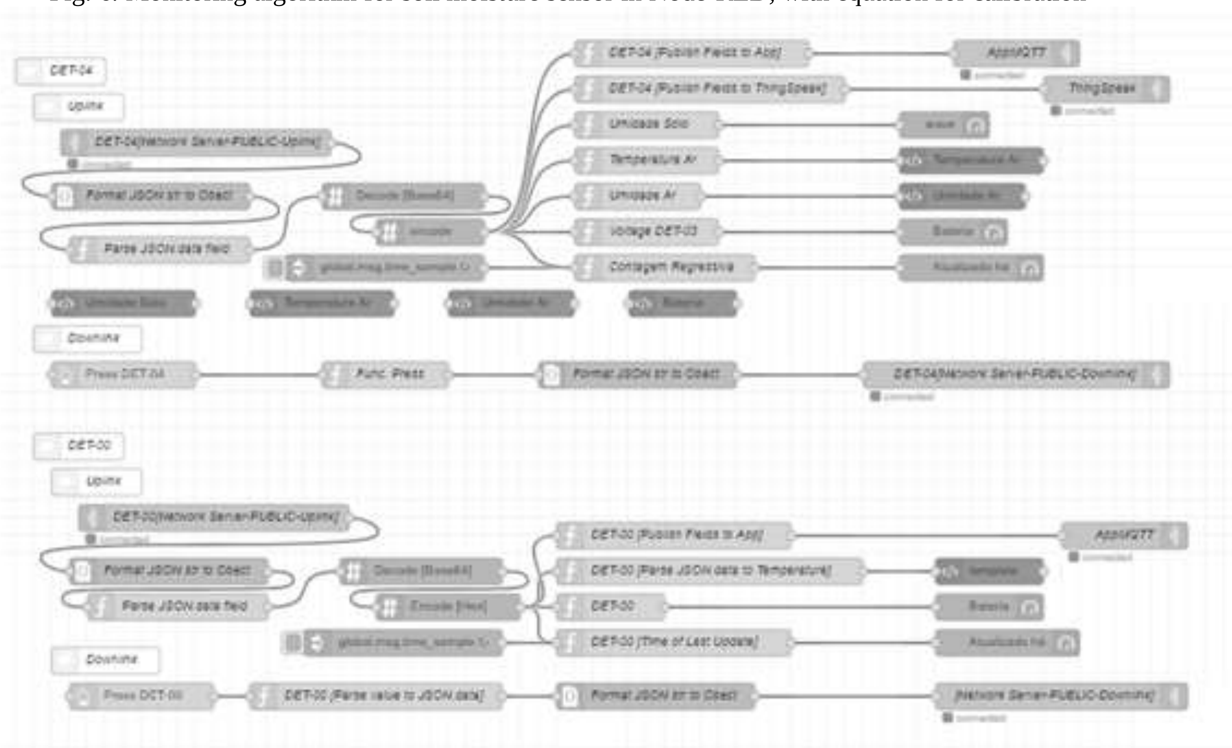


Fig. 7. Calibration Curve for Capacitive Sensor

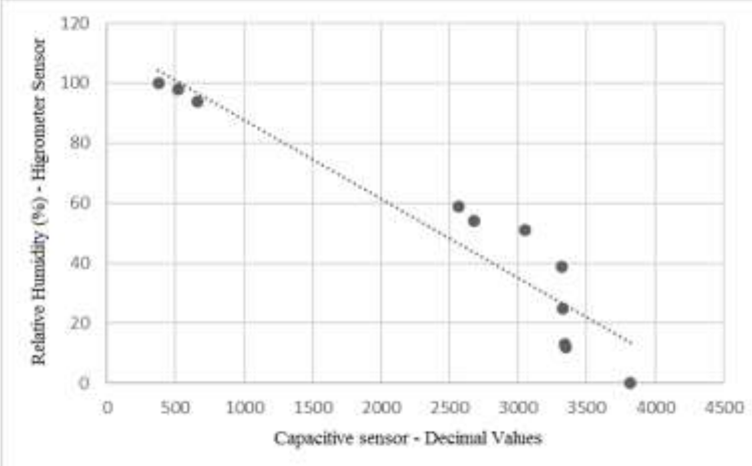


Fig. 8. Level Control WebLab. oT MQTT Panel user interface.

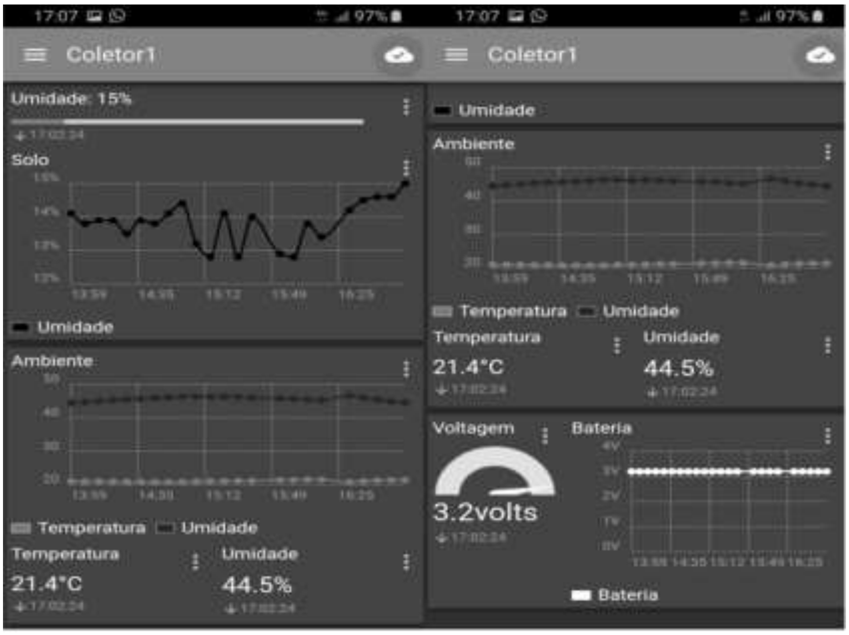


Fig. 9. Dashboard.

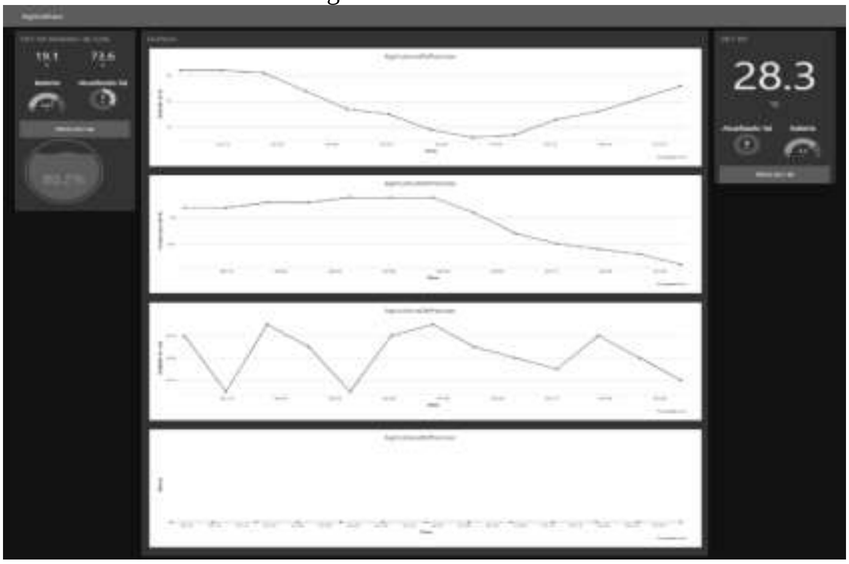
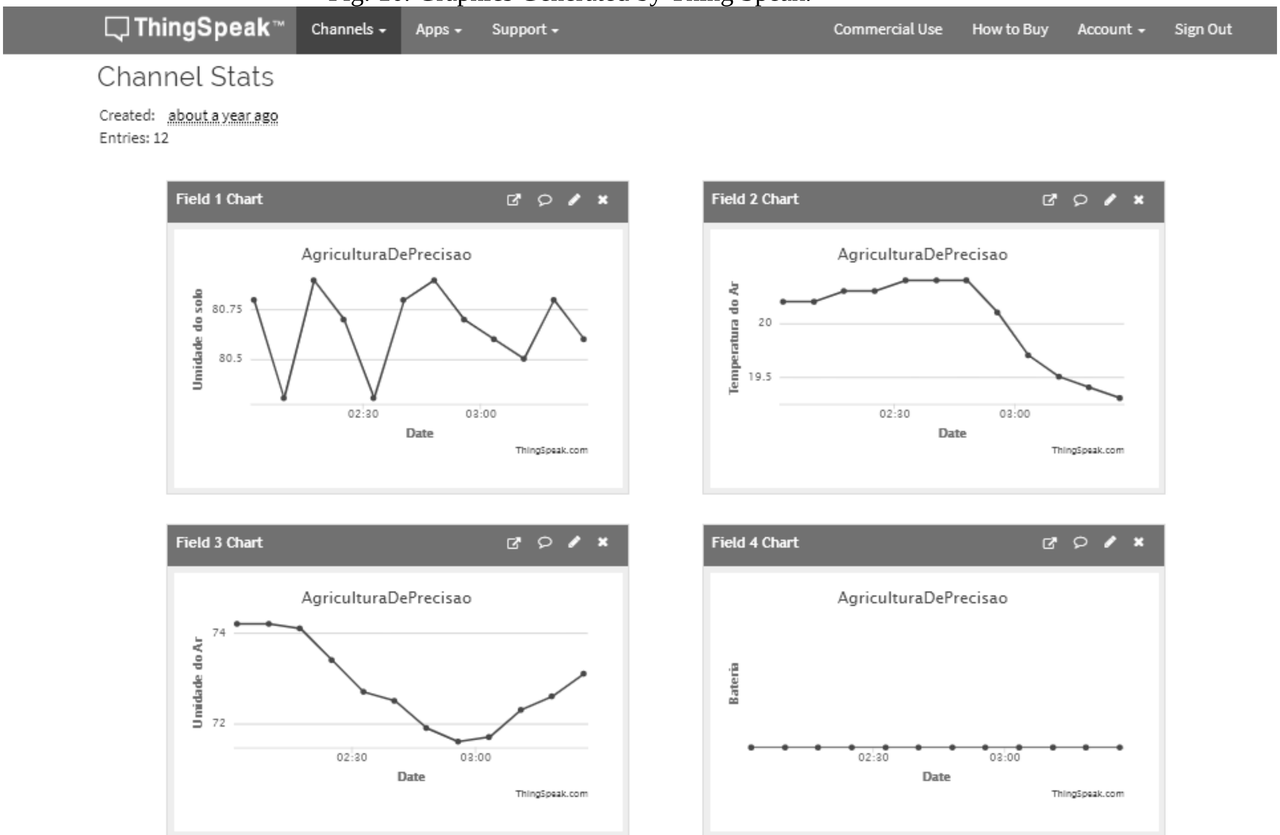


Fig. 10. Graphics Generated by Thing Speak.



6 CONCLUSIONS AND FINAL REMARKS

The premises defined for the work were successfully achieved, that is, the development of a system to monitor data from atmospheric sensors and soil moisture sensors. Besides that, were created interfaces so that the data is available to users, accessing different platforms (computers, mobile devices). The developed interfaces are intuitive and present the measured instantaneous values, including the values calibrated from soil moisture sensor. In addition, they present graphs showing the historical register of data, which can be used to develop forecasting algorithms.

The communication system using the LoRaWAN^{TM} protocol proved to be efficient and with considerable reach, in addition to producing reduced consumption, making the use of the system powered by batteries viable.

From the signals collected by the sensors, other continuity projects will be developed, which include:

- construction of three-level sensors to detect moisture at different depths;
- monitoring of other variables of interest, such as soil pH;
- development of an intelligent system based on neural networks to automate the irrigation process; the irrigation system using a flow controller and sprinklers has already been built and will be presented in other works;
- development of a system for monitoring plant growth in real time using an image processing algorithm;
- definition of appropriate humidity conditions for the specific type of planting;
- evaluating of different irrigation techniques and their impact on soil moisture, and as a consequence on plant growth.

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REFERENCES

[1] R. Rajeswari; K. Suthendran and K. Rajakumar, "A Smart Agricultural Model by Integrating IoT, Mobile and Cloud-based Big Data Analytics". International Conference on Intelligent Computing and Control (I2C2). v. 118, nº 82018, pp. 365-370, 2017.

[2] J. P. Coelho and J. R. Silva, "Agricultura de Precisão", 1st edition. ISBN 978-989-8319-04-3, Lisboa, Portugal, 2009.

[3] A. Tzounis, N. Katsoulas, T. Bartzanas, C. Kittas, "Internet of Things in agriculture, recent advances and future challenges" Biosystems Engineering, v. 164, pp. 31-48, December, 2017.

[4] N. Dlodlo, J. Kalezhi "The Internet of Things in Agriculture for Sustainable Rural Development" 2015 International Conference on Emerging Trends in Networks and Computer Communications (ENTCC), Windhoek, Namibia, May, 2015.

[5] P. P. Jayaraman, A. Yavari, D. Georgakopoulos, A. Morshed and A. Zaslavsky, "Internet of Things Platform for Smart Farming: Experiences and Lessons Learnt". Sensors 2016, v. 16, pp. 1884.

[6] Maia, R. F.; Netto, I.; Tran, A. L. H. "Precision Agriculture Using Remote Monitoring Systems In Brazil" IEEE Global Humanitarian Technology Conference (GHTC), San Jose, CA, USA, 25 December 2017.

[7] S. Li "Application of the Internet of Things Technology in Precision Agriculture Irrigation Systems", 2012 International Conference on Computer Science and Service System, Nanjing, China, August, 2012.

[8] B. G. L. Dias, A. D. Coelho, W. O. Assis, F. A. Martins, R. C. Pires, "Monitoramento de Sensores de Umidade do Solo com Internet das Coisas (IoT) Aplicado na Agricultura de Precisão" 11° Seminário Mauá de Iniciação Científica, São Caetano do Sul, SP, Brasil, 2019.

[9] G. Bitella, R. Rossi, R. Bochicchio, M. Perniola, and M. Amato, "A Novel Low-Cost Open-Hardware Platform for Monitoring Soil Water Content and Multiple Soil-Air-Vegetation Parameters". Sensors 2014, v. 14, pp. 19639-19659.

[10] J. Ma, X. Zhou, S. Li, Z. Li, "Connecting Agriculture to the Internet of Things through Sensor Networks", 2011 International Conference on Internet of Things and 4th International Conference on Cyber, Physical and Social Computing, Dalian, China, October, 2011.

[11] Usmonov, M.; Gregoretti, F. "Design and Implementation of a LoRa Based Wireless Control for Drip Irrigation Systems" 2nd International Conference on Robotics and Automation Engineering, 2017.

[12] Zhao, W.; Lin, S.; Han, J.; Xu, R.; Hou, L. "Design and Implementation of Smart Irrigation System Based on LoRa" IEEE Globecom Workshops, Singapore, 4-9 December, 2017.