AgronomoBot: a smart answering Chatbot applied to agricultural sensor networks

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Abstract. *Mobile devices advanced adoption has fostered the creation of various messaging applications providing convenience and practicality in general communication. In this sense, new technologies arise bringing automatic, continuous and intelligent features for communication through messaging applications by using web robots, also called Chatbots. Those are computer programs that simulate a real conversation between humans to answer questions or do tasks, giving the impression that the person is talking to someone else and not with a computer program. For agricultural purposes, it is important that the data about field conditions, such as air and soil temperature, air relative humidity, soil moisture, rainfall, wind speed and other relevant variables, be rapid and easily available for use by farm management systems, by specialists, or the farmer itself in decision-making processes. AgronomoBot was developed focused on the search and display of data acquired from a Wireless Sensor Network deployed on a vineyard. It is based on Telegram Bot API and is able to access information collected by eKo field sensors, bringing it back to a user through interaction over the Telegram application. The IBM Watson cognition services platform was also used for improving the user experience by enabling the use of natural language during the conversation experience, providing intention detection. Further developments are planned for AgronomoBot, such as the expansion to other messaging platforms, the implementation of speech communication capacity, image classification and continuous data analysis. It is hoped that with analytical capacity over the mass of available data, it becomes possible to work towards the prevention of harmful situations to agricultural productions, early detection of diseases in crops, energy and water waste reduction, and advanced management capabilities for the farmer.*

Keywords. *Chatbot, Wireless Sensor Networks, Internet of Things, Artificial Intelligence, Watson, Telegram.*

Introduction

Consolidation of smartphones connected to the Internet is fostering the creation of several technologies, capable of helping in a variety of tasks, which were never thought possible in such an easy way. The mobility and ubiquity granted by these devices are driving the paradigm shift from Web 3.0 to Web 4.0 that have been treated as a web of symbiosis between human and machines.

Within this universe, advances in messaging applications, Artificial Intelligence (AI) and the need for extreme customization creates a favorable scenario for the development of chatbots, capable of replacing current applications. Gartner leaders point out that by 2020 people will no longer use apps on their smartphones. They will still exist, but will no longer be noticed, since people will rely on virtual assistants for the interaction.

On the other hand, according to Queiroz et al. (2008), agriculture shows a growing adoption of new technologies, and an intensified use of electronic devices and business models, in order to improve product quality, increase production, reduce costs and the impact on the environment. In this context, Wireless Sensor Networks (WSNs) enables variable monitoring on different agricultural production chains, and that is essential in order to generate the information necessary for decision making, both in processes control systems and at the management of production chains.

Currently, in wine production, a lot of the analysis performed by specialists (agronomists or winemakers) are done in-field and manually, which makes data acquisition and interpretation arduous and time-consuming.

In this context, the development of an application based on artificial intelligence and capable of interacting with the expert is necessary, for providing the desired information from the WSN deployed on the field, quickly and directly, at any time and place, in a way that all the enabling mechanism is invisible to the end user.

Objectives

This work aims to implement, as a proof of concept, a Chatbot that promotes remote interaction of the user to the wine production environment using natural language, in order to In this sense the Telegram API Bot was used together with IBM Watson Conversation, providing support for data acquisition from an eKo WSN deployed on a vineyard.

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Literature Review

Wireless Sensor Networks

Wireless Sensor Networks (WSN) are a phenomena-sensing resource, with a distributed architecture, encompassing the dissemination of the collected data and the processed information to one or more observers (ZHANG et al., 2015). They intend to monitor environments and are mainly used in areas of difficult access, where it is not feasible to install cables for power or data transmission.

According to Campos and Cugnasca (2014), WSNs have great potential for the observation and control of the real world, standing as a suitable solution for the most diverse areas, and among them the Intelligent and Precision Agriculture that relies on the constant monitoring of the climate, soil, plants and animals, granting a fast, efficient and guided decision making process, increasing productivity and reducing losses in the field.

Cognitive Computing

Cognition is a process of the human mind responsible for creating knowledge and understanding, obtaining an abstract representation of reality. Cognitive Computing can be defined as a discipline that integrates concepts of neurobiology, cognitive psychology and artificial intelligence (MODHA et al., 2011). Three important concepts should be noticed in order to classify a system as cognitive, they are: contextual insight form the model; hypothesis generation and continuous learning from data across time (HURWITZ et al., 2015).

Cognitive computing systems usually consist of tools and techniques that include Big Data and Analytics, Machine Learning (ML), IoT, Natural Language Processing (NLP), causal induction, probabilistic reasoning and data visualization. Cognitive systems have the capability to learn, remember, provoke, analyze, and resolve in a manner that is contextually relevant to the user (HURWITZ et al., 2015).

The authors Kelly and Hamm (2013) say that the changes driven by cognitive computing over the next two decades will transform the way we live and work, and can be compared to the revolution that computing has caused in human life over the past 50 years. They further affirm that the growth of volume data on the Internet is paving the way for systems with cognitive abilities, searching for interconnections and structures in unstructured data. Because they have the capabilities mentioned above, they are better suited than traditional software to analyze data and offer adaptive solutions.

Artificial Intelligence

Web 3.0, or semantic web, that potentiated the organization and systematization of online content, making the searches more assertive, now undergoes a new transformation towards Web 4.0, which, although it does not yet have a clear definition, is being treated as a web where humans and machines interact in symbiosis. Scholars point towards a large dynamic operating system, working in parallel with the human mind, implying a massive web composed of highly intelligent interactions, and it is only possible with the use of Artificial Intelligence (AI) (AGHAEI et al., 2012).

In this perspective, AI is derived from human intelligence itself and from human nature, aiming at bringing intelligence and knowledge to a virtual brain, trying to not only understand the world, but to construct intelligent applications in order to expand the reach of innovations in the Information Technology market (RUSSEL; NORVIG, 2010). Poole and Mackworth (2017) state that among the central objectives of AI research are: to analyze natural and artificial agents; to formulate and test hypotheses about what is necessary for the creation of intelligent agents; to design, study and conduct experiments with computational systems to perform tasks that require intelligence.

AI is a great ally of the conversational agents because using it in chatbots expands their capacity for understanding and response. One common application in chatbots involves the use of Natural Language Interaction (NLI) and consequently Natural Language Processing (NLP), which is designed to simulate a human conversation. The advantage of using it relies on the ability to use structured phrases (with verbs, nouns, adjectives, etc.) to provide a response more sensitive to the intents of the question (HIGASHINAKA et al., 2014).

Natural Language Processing

Natural Language Processing (NLP) is a theory-motivated range of computational techniques for the automatic analysis and representation of human language (CAMBRIA; WHITE, 2014). According to Lehnert and Ringle (2014), research on NLP should not be mistaken by speech recognition but is concerned with the symbolic manipulations of meaning and interface that are needed once words are recognized. In fact, a speech recognition algorithm needs to be paired to a language processing program in order to implement actual verbal dialogues with computers.

The authors Cambria and White (2014) state that NLP research is in a paradigm shift, they are no longer based on techniques of recognition and understanding of loose words. But now begin to explore semantic techniques more consistently, which the authors call a jump from syntactics curve to the semantics curve, and ultimately will arrive at the pragmatics curve, where computational programs will be able to investigate and build entire narratives.

Chatbots

New technologies have favored the creation of intelligent and autonomous systems, and among them is the emergence of Chatbots. The term “chatbot” or “chatterbot” indicates a robot that can talk and can be defined as a software that allows the simplification of interactions between humans and machines.

These interactions can occur through speech or writing in the natural language, through motion sensors, interaction with devices, and in other ways. According to Hill et al. (2015), humans can easily adapt their language to human-chatbot communication, although there are notable differences in the content and quality of these conversations. Results presented by the authors show that people communicate with chatbots for longer periods, but with shorter messages when compared to human conversation. Also emphasizing that human-chatbot communication has impoverished the vocabulary used by humans and increased in the occurrence of profanity.

Chatbots can be categorized in two ways: (i) rules-based, operating by means of specific commands (or keywords), which generally obey well-defined navigation flows and produce targeted conversations; (ii) AI-based, making use of more advanced technologies such as machine learning, NLP, among other artifices to increase its capacity for dialogue and interaction.

The engine is the most important feature of a chatbot. It is responsible for the transformation of natural language into machine-understandable actions. Chatbots engines are usually developed using several Natural Language Processing and Machine Learning models to provide acceptable levels of accuracy (KAR; HALDAR, 2016).

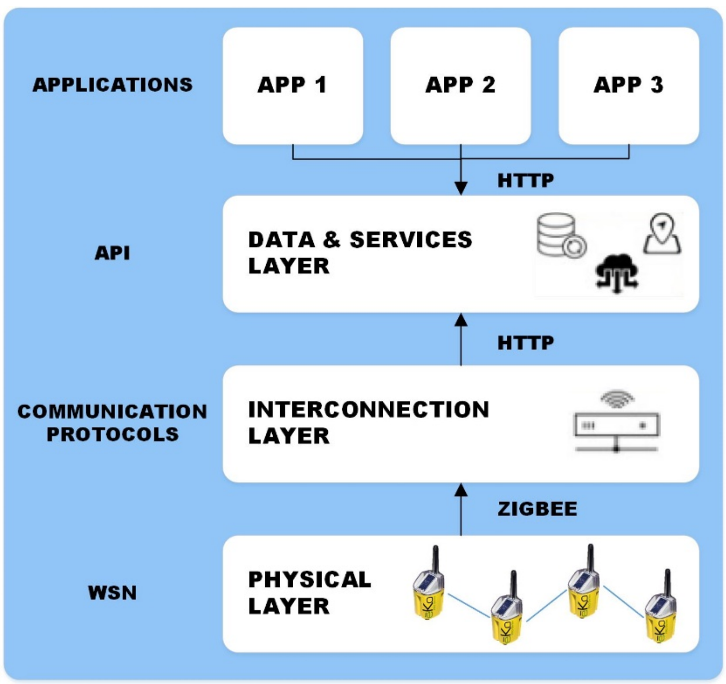
For this project, the IBM Watson Assistant engine is used for the implementation of a chatbot. The Conversation feature enjoys a set of ML and NLP resources capable of extracting intentions and entities from a dialog and thus produce a more precise response.

Material and Methods

An API developed by Souza (2017) was used as a source of information for the Chatbot search. It contains the complete database of an eKo WSN implemented in a commercial vineyard with data collected during the year of 2016. For a dialogical user-bot interaction, the Telegram Messenger service was used as the communication interface, since this messenger has an open API for chatbots development, including several features like sharing text, audio, video and documents. The dialogue interpretation was done by IBM Watson Assistant through NLP and ML.

WSN Architecture

For the realization of the project, data collected by a WSN as described by Souza (2017) were used. This data was centralized and made available through a REST API. It is represented, in Figure 1, the architecture of the API starting with the Physical Layer, formed by the nodes and sensors of the eKo WSN. This layer is responsible for collecting and sending data to the Gateway present in the Interconnection Layer, using the ZigBee network.



Font: Adapted from Souza (2017).

Fig. 1. WSN architecture.

The Interconnection Layer is intended to provide communication between the WSN Nodes, the Gateway and the Services. In this layer, the mechanisms for synchronization between the Physical Layer and the Data and Services Layer are implemented. Once the records arrive at the Gateway, they are organized into a JavaScript Object Notation (JSON) structure and sent to the API via the POST method.

Finally, the Data and Services Layer is responsible for storing and making the data available to other Web applications through an API. The API was implemented by following the Representational State Transfer (REST) model proposed by Souza (2017). In this model, all resources and information are made available through Uniform Resource Locators (URLs). All information exchange between applications with this layer is performed through Hypertext

Transfer Protocol (HTTP) requests implemented by the methods (GET, POST, PUT, DELETE).

Through the API it is possible to retrieve data from the sensors and nodes of the WSN, as well as persisting new data such as the inclusion of a new node. Table 1 shows REST API routes, with their associated HTTP verbs and a description of actions that can be performed on each route.

Table 1. API routes.

URL	HTTP verb	Sensor	Monitored Variables
http://ipservidor:2500/v1 /registros/es1201	GET/POST	ES1201	Relative Humidity, Temperature, Dew point
http://ipservidor:2500/v1 /registros/es1110	GET/POST	ES1110	External soil moisture
http://ipservidor:2500/v1 /registros/es1301	GET/POST	ES1301	Leaf wetness
http://ipservidor:2500/v1 /registros/es1401	GET/POST	ES1401	Solar radiation
http://ipservidor:2500/v1 /registros/es1100	GET/POST	ES1100	Internal soil moisture

Font: Adapted from Souza (2017).

Each request to one of these URLs, combined with HTTP verb GET brings a JSON document containing all the stored records of a particular sensor. In this sense, if an application requires only one variable, the API can make it available separately, thus avoiding unnecessary data handling. In addition to the external sensors, each node of the WSN has internal devices to monitor solar energy capacity and battery charge.

Chatbot Definitions

The AI-based chatbot was chosen based on the proximity to the experience of dialogue with a human being it can bring. This is so, due to the understanding that is given by the NLP and ML algorithms, which enables it to draw the same meaning from a dialogue, even when expressed in different ways.

The chatbot knowledge areas were categorized into two groups: technical knowledge (Resources) and extra knowledge (Others). The technical knowledge area is in charge of the search of information from the WSN in the database through API. The extra knowledge area was created to make chatbot behavior more human-like. This area consists of dialogue such as greetings, options menu and help sections, making the chatbot more social. Figure 2 lists the functionalities in each knowledge area.

Fig. 2. Knowledge areas diagram.

For the chatbot development, three modules are essential: (i) a human-computer interface, where the user can communicate with the chatbot; (ii) the IBM Watson Assistant service, where the dialogs are interpreted; and (iii) the WSN API, where the information of sensors and nodes comes from. Figure 3 shows the proposed architecture for the integration of these modules, which are detailed in the following items.

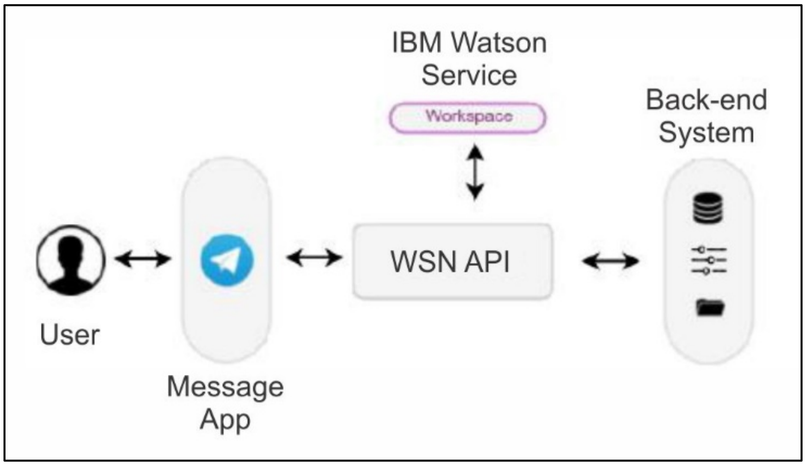


Fig. 3. Chatbot Architecture.

Telegram Conversation Interface

The Telegram Bot API [https://core.telegram.org/bots/api] allows the creation of chatbots capable to connect to their messaging system. Telegram Bots are special platform accounts that do not require an additional telephone number for setup. These accounts serve as a dialog interface capable of executing instructions programmed through their API. The Telegram itself uses a bot (BotFather), based on rules for the creation of the others. At the end of the process, an authorization token is granted, in order to direct the received messages to the bot created (Figure 4).

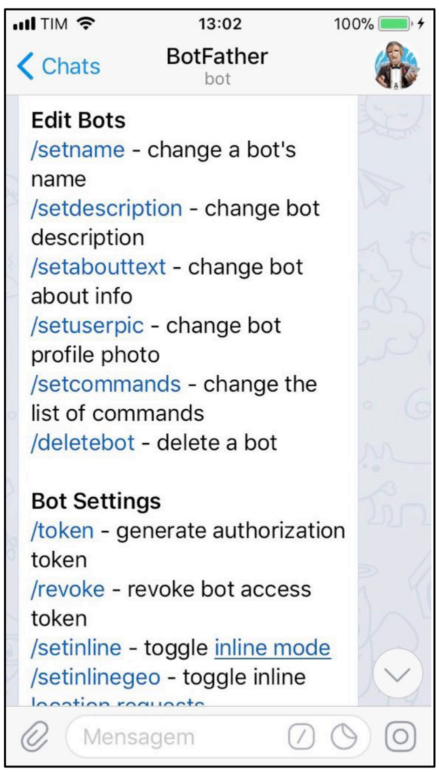


Fig. 4. BotFather setup screen.

Natural Language Understanding Module

The first step in the setup of an engine for the chatbot is also the most important since it defines the rules. Development was made easier since a graphical interface is available for its definition. Users' possible intentions were defined based on the diagram in Figure 2. In total, the bot can recognize seven possible intentions during the conversation. Figure 5 shows the intentions created through IBM Watson.

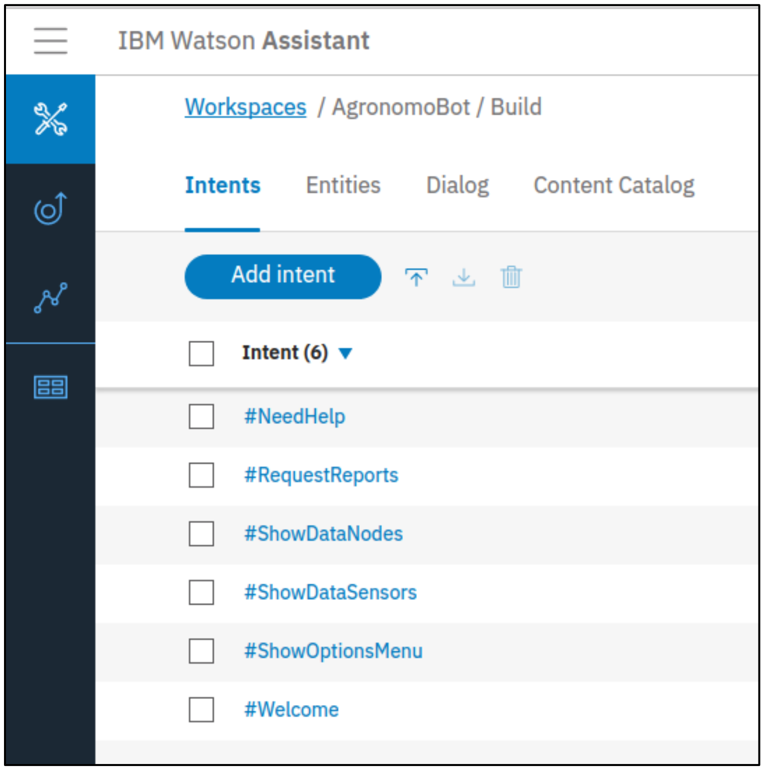


Fig. 5. Chatbot intention setup on IBM Watson.

For each intent, one should provide examples of possible queries illustrating different ways to accomplish that request, over which IBM Watson will train the conversation model for pattern recognition. It is worth noting that IBM Watson has the ability to learn with new dialogs that are performed with the user, as long as the inserted message fits the desired intention.

Identifying the user's intention is of great importance for the development of the dialogue. However, in addition, it is essential to know about which entity that intention is concerned. In this sense, two entities were defined for chatbot, they are Node and Sensor. This grouping was done based on the application domain, according to the data present in the API of the WSN.

In order to unite the user's intention with the related entity, the flow of dialogues was created. It functions as a decision tree, where conditions are evaluated as true or false in order to determine the flow of the dialogue. In the dialog flow developed, the tree has only one level of split in eight possible leaves, corresponding to the seven intentions and an additional option for cases outside any of the intentions, caused by a lack of orientation in the request made or a classification error.

For each leaf in the tree of dialog flow, the requirements for classification must be determined, in addition to the chatbot response alternatives in that situation.

Module Integration Application

In order to integrate the conversation interface and the natural language understanding modules, an application has been developed to send the Telegram bot messages to IBM Watson Assistant and consult information of the WSN through its API.

The program was developed using Node.js technology [https://nodejs.org/en/], in addition to the node-telegram-bot-api libraries [https://github.com/yagop/node-telegram-bot-api] and watson-developer-cloud [https://github.com/watson-developer-cloud/node-sdk#conversation]. Node.js is a platform for developing network-based server-side applications using JavaScript and V8 JavaScript Engine 3 (TILKOV; VINKOSKI, 2010). Finally, to turn this solution public and in constant execution over the internet, the cloud computing platform services from Heroku [https://www.heroku.com/] were used for the deployment. The latter provides a free container-based Platform as a Service (PaaS) cloud environment that provides a complete cloud development and deployment environment. The program coding can be found in the AgronomoBot repository [https://github.com/icaroramiires/agronomobot].

Results and Discussion

Based on the research here described, it was possible to provide an AI-based chatbot application to assist the specialist in the acquisition of climate and soil data through a WSN. As a proof of concept, the AgronomoBot was developed, a chatbot that uses NLP and AI to interact with the user and search for the desired information in a WSN, adapting to different forms of dialogue to achieve the same intention. Next, the functionalities developed for the chatbot system are demonstrated. The dialogues shown in this section were translated from Portuguese to English for a better understanding of their content, although AgronomoBot can easily be adapted to any language, supported by the NLP algorithm used for its development.

Intention 1: Greetings

For an initial interaction with the bot, a greeting interaction instance was developed in order to make AgronomoBot more receptive to the user, showing itself available and prepared to assist the interlocutor.

Intention 2: Help

A help section is important since it is common to expect some difficulty on understanding the chatbot functionalities during the first contact, or maybe during the conversation, when the user wishes to confirm some details of an operation. In this sense, the chatbot is able to detect when the user has any doubts or problems and try to help him (Figure 6).

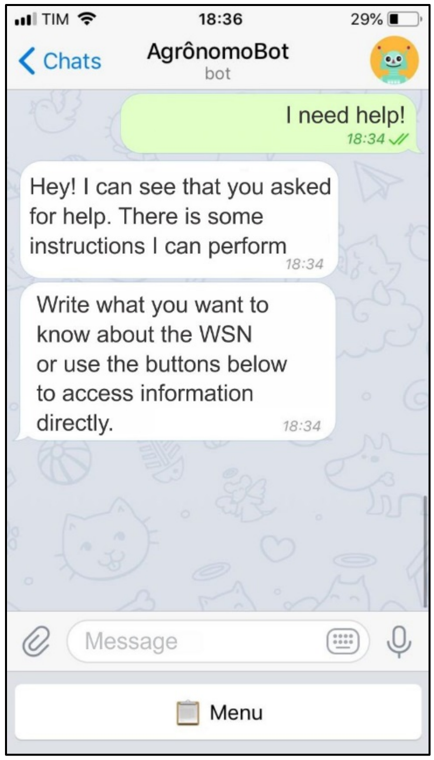


Fig. 6. Help request dialogue.

Intention 3: Options Menu

A menu of options can be offered to the user if he chooses a more intuitive and direct interface, in which buttons are displayed for the interaction with the bot. This was only possible due to the Telegram API resources library node-telegram-bot-api. This feature was implemented only to increase the usability in case that a direct access to the bot resources is needed. The options and features provided by the menu can be seen in Figure 7.

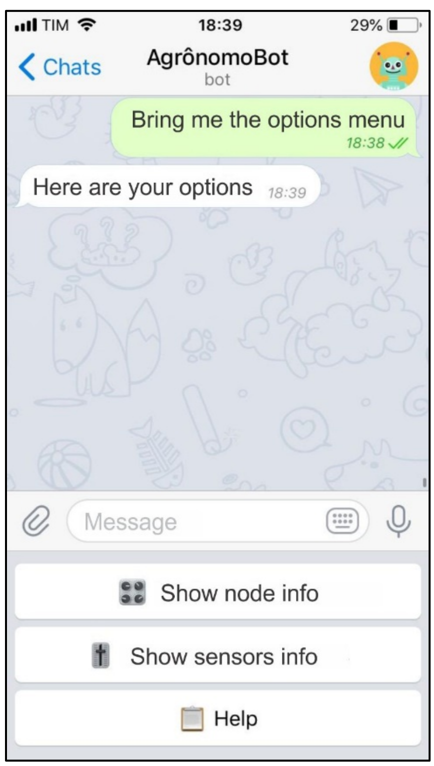


Fig. 7. Options Menu request dialogue.

Intention 4: Information request

Through this intention, interaction with the WSN occurs and the data is returned to the user. By connecting the "know something about" intention and the defined entities (node and sensors) AgronomoBot was able to request the data of the sensors and nodes to the WSN installed in the vineyard environment, and inform it to the user via text message. In the example shown in Figure 8 is the request for data about the sensors and the response containing information about them.

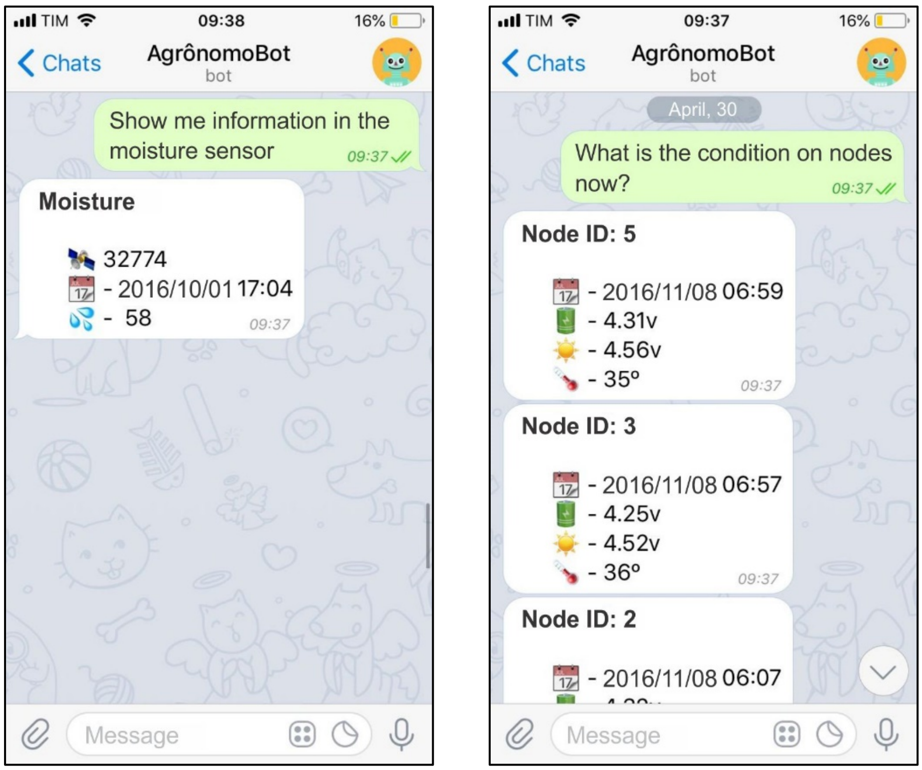


Fig. 8. Information request dialogue, sensor (left) and nodes (right).

Intention 5: Reporting

With this intention, it was possible to enjoy more advanced features than the ones before, via isolated text messages. Similarly to the intention Information request, the "issue a report on" intention also works together with the node and sensor entities. However, this time AgronomoBot starts to process information from the WSN and generate statistical metrics for its components, presenting the results as graphics in a “.png” image format or reports formatted as a ".pdf" document. The return from both options for presenting results is shown in Figure 9.

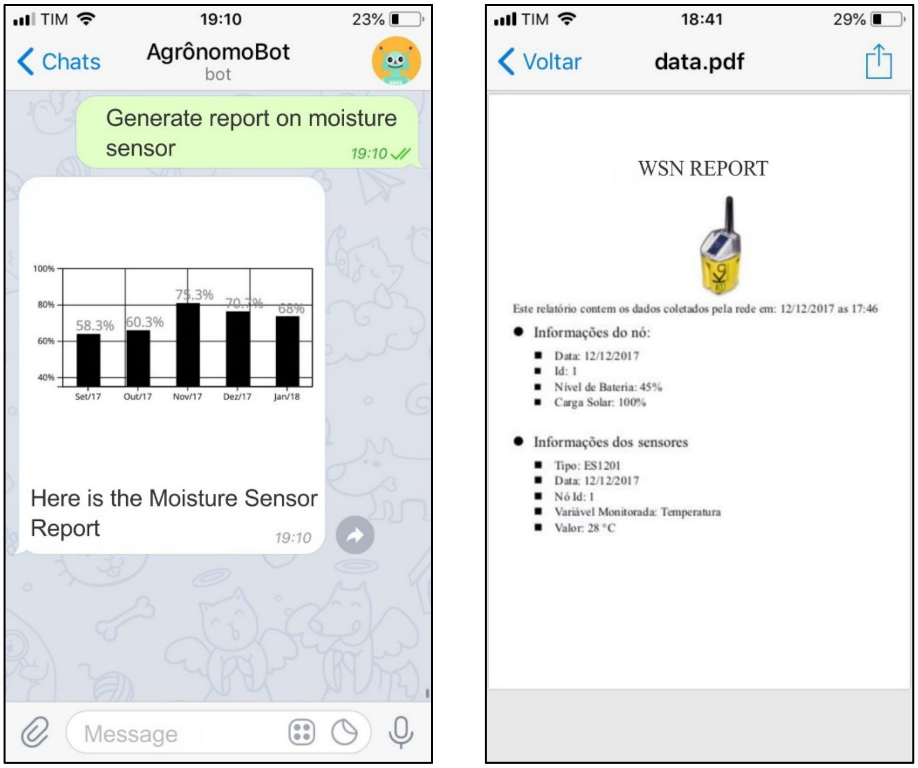


Fig. 9. Report request dialogue, graphic (left) and document (right).

The research carried out in this work provides a chatbot, named AgronomoBot, which aims at assisting the specialist on the acquisition of data of variables related to soil, plants and climate, collected by a WSN, and in decision making based on field reports.

Chatbots have great potential to act on issues such as monitoring and acquiring data in WSNs. Because it is based on cloud services it can have unlimited capacity and act continuously, serving multiple users at the same time. In addition, the access is remote and can be carried out using a smartphone or a computer with internet access.

Given the observed aspects, the use of chatbots for data acquisition in agriculture provides great help, as it automates data collection and variable monitoring while providing the user with a pleasant experience due to its efficiency, effectiveness and usability. In this sense, AgronomoBot corresponded the interactions in a satisfactory way, capturing the user's intention on a certain subject and delivering the required information. The ability to handle more advanced features such as sending images and documents enhances chatbot's functionality, not limiting it to text message interaction, bringing the bot experience even closer to a human conversation.

AgronomoBot is a proof of concept of a chatbot with NLP and AI capabilities, which takes the first step by facilitating human-machine communication and paves the way for more robust and complex implementations, in which we can include prediction of pests and diseases occurrence, a variety of alerts for the production, from frost to quotation of products and inputs, automatic or supervised control of irrigation and the operation of machines and implements, image recognition with the aid of Machine Learning, among a wide range of possibilities for the agricultural environment. But always placing first the interactivity, which is guaranteed by the ease of use, efficiency in the detection of intentions, ability to perform tasks and quality in the answers presented by the conversational algorithms.

As future work we can relate the implementation of speech communication capacity via speech-to-text and text-to-speech, embracing the specificities of spoken communication, more fluid and rich in idiomatic expressions. Further enhancing interactivity and bridging accessibility gaps for people with disabilities or difficult interaction with devices. In addition, it is intended to expand

AgronomoBot to other messaging platforms, which provide the basis for chatbots implementation, as well as new functionalities such as the classification of images sent by messaging applications and continuous data analysis.

It is also intended to use the large amount of data produced by the sensors in surveys related to data mining for knowledge discovery, thus expanding the capabilities of the models behind the chatbot, and enabling it to send notifications about any possible situations that may occur in the field or malfunctions in the operation of the WSN and its sensors.

Conclusion

It was possible to achieve the objectives, presenting a satisfactory solution for the search and display of data on a WSN applied to wine production, based on the use of natural language that combines the functionalities of the electronic message service Telegram and the power of the cognitive services platform Watson from IBM.

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