Data Science and Pattern Recognition ©2017 ISSN 2520-4165
Ubiquitous International Volume **1**, Number **1**, February **2017**

SenseQ: Replying questions of Social Networks users by using a Wireless Sensor Network based on sensor relationships

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Abstract. *Social Networks are a way of establishing communications with friends or family and a way of knowing what happens around us. However, there are not machines that provide users with information about their worries. What happens if a user wants to know if it is raining in a specific place at that moment? He needs to ask a person who is in that place at that moment. Why not take advantage of the Internet of Things to collect information in real time and answer users questions? The Internet of Things is a field that tries to measure everything by gathering data from sensors and interconnect different objects. Why not combine Social Networks and the Internet of Things? In this paper, we propose the development of a new system that will allow users to ask for information to a network of sensors through Social Networks, concretely in this case through Twitter. The system will have sensors registered by different users and this system that will be used to answer questions of other users. The system will be able to collect information of users sensors, process it, and use it to answer users questions through Social Networks. In order to gather the data from sensors and combine them, we propose three different types of relationships between sensors: neighboring relationship, familiar relationship and working relationship. Besides, we propose an architecture based on three layers: social layer, backend layer and object layer.*
Keywords: Social Networks; Sensors; The Internet of Things; Twitter; WSN.

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1. **Introduction.** Social Networks (SN) are very present in our lives. Many of us share all aspects of our life on Social Networks like posting messages about what we are doing at that moment, sharing photos with friends, giving our opinion about other posts and so on. Moreover, Social Networks are also used by business to promote their products or services and even, SNs are a new channel of communication between companies and clients.

Furthermore, Social Networks are also a data source where users can search any type of information like the closing time of a shop, the restaurants phone, the weather in a specific zone through the profile of an expert and so on. However, this information is not in real-time since users read posts written some time before. For example, a user can read the temperature of a place through a post of a weather forecast profile but it has not posted the necessary information in that moment. In this paper, we will present our proposal of an accessible information source via Social Networks. The information that we want to provide is the data gathered by many sensors in real-time. Hence, we propose the combination of Social Networks and the world of the Internet of Things (IoT) to inform the users about any data available in our Wireless Sensor Network (WSN). To achieve this goal, we propose the creation of a novel system that will answer questions made by Social Networks users using natural language by consulting data gathered by different sensors, which will be available in a specific WSN. Thus, we want to make sensor data accessible through Social Networks for any user in an easy way.

The Social Network that we have chosen for this proposal is Twitter because how it works. Twitter is based on short messages with certain semantics that makes easier work with them. But the more important characteristic of this Social Network for this proposal is that it does not require reciprocation of its users relationship [1]. This means that users do not need to be followed by users that the first ones follow and vice versa.

Currently, there are many references to the Internet of Things around us. Some references could be the smartphones, wearables, tablets [2] or any other device with Internet capabilities. These smart devices are also called Smart Objects. The world of IoT allows the creation of many smart environments like Smart Homes [3][6], Smart Towns [7], Smart Cities [8][11] or Smart Earth [8], [12]. These new possibilities can exist due to the combination of different Smart Objects or Not-Smart Objects [13] like actuators or sensors. Our proposal is based on a system that collects information from a sensor network to answer questions that users make through Social Networks. In this paper, we will present a proposal of integration of Social Networks and the Internet of Things [14] in order to research how technologies of the Internet of Things can communicate with humans through Social Networks and how they could obtain and collect information to help and answer people questions. The remainder of this paper is organized as follows. In Section 2, we are going to introduce involved topics in this research. Section 3 is going to show our proposal, the system to answer questions of users by using sensor networks through Social Networks and Section 4 is going to contain the conclusions of this paper and the possible future work that could be done from this proposal.

2. **State of the Art.** In this section, we will present a theoretical frame about the concepts involved in our proposal. These concepts include the Internet of Things, Smart Objects, Social Networks, and Natural Language Processing (NLP) because our proposal could be interpreted as a way of make queries to Smart Objects from the Internet of Things through Social Networks using Natural Language.

2.1. **The Internet of Things.** The term the Internet of Things (IoT) is defined as the interconnection of heterogeneous and ubiquitous objects between themselves [4], [15][18]. The concept includes not only the connection between objects, also known as Machine-to-Machine (M2M) [19][21], but also the communication between humans (H2H) [21] and Humans to Machines (H2M) [22].

There are many topics of research that address the IoT in a large range of fields. Related research topics to our proposal may be the topics that address the IoT and Social Networks.

The Social Internet of Things (SIoT) [17] combines the IoT and Social Networks obtaining a new generation of objects, the social objects. These objects are capable of interacting with other objects by themselves. They are able to discover services and useful information from other objects because all of them share their services and information in the network [23].

Using Social Networks in combination with the Web of Things has some benefits, for instance, the integration of Smart Objects in Social Networks that was proposed in [24]. They explored the possibility of integrate applications inside some Social Networks like Facebook in order to integrate Smart Objects in that Social Network. Moreover, the combination of IoT technologies with the habits of using Social Networks helps people to familiarize themselves with the IoT according to scientists of Ericsson [23].

2.2. **Smart Objects.** In the definition of the IoT, we mentioned the word objects. In the IoT, the objects usually have some type of intelligence and therefore, they are called Smart Objects. The Smart Objects are objects with an embedded system that allows them to process information, communicate with other devices and perform actions based on other actions or events [4].

According to [4], [25], Smart Objects can be classified into three levels: Level of Intelligence, Location of Intelligence and Aggregation Level of Intelligence. Examples of Smart Objects can be smartphones, micro-controllers like Arduino [4], [26], [27] or any other object connected to the Internet and capable of handling information. Frequently, these Smart Objects are composed of other objects without intelligence like sensors or actuators that can be called Not-Smart Objects [13]. Using these Not-Smart Objects, Smart Objects can sense the environment and perform actions. The combination of the IoT and Smart Objects achieves that the network not only transports data but also provides intelligence and actions.

2.3. **Social Networks.** A way of integrating applications in our lives is adding social aspects to the applications. Good resources for that propose are Social Networks. Many SNs provide several Application Programming Interfaces (APIs) that allow reading or writing in timelines, receiving or sending private messages or updates, and so on. The convergence of the real world with SNs is an important piece of the Web 2.0 because SNs like Facebook or Twitter allow their users to communicate, exchange and share contents. Thus, creating applications that interconnect things and humans is also possible [24].

Currently, there are many available Social Networks to use for research purposes although we have chosen Twitter due to its way of work based on short messages composed by keywords, which are called hashtags. Furthermore, Twitter is suitable for this research although it has some limitations.

Social Networks are usually used to collect data about events or people, that can be useful for research purposes. However, we propose the use of Social Networks to give new information to users, instead of collecting data from Social Networks. Users will have to ask for the information that they want and our proposal will have to be capable of understanding their requests through natural language processing like in [28]. In [28], the authors use Twitter to extract information about traffic events using NLP.

As we have already explained before, we have chosen Twitter because of a concrete characteristic of this Social Network, it does not require reciprocation of its users relationships [1].

In order to link the Internet of Things and Twitter we can consider some previous investigations like [29] where the authors consider humans as another type of sensor, [30] where Twitter is used to detect Earthquakes, or [31] where the authors propose support decisions about the destination of tourism according to the posts of Twitter users.

2.4. **Natural Language Processing.** Natural Language Processing (NLP) is a branch of the Artificial Intelligent (AI) whose aim is to try to resolve the problem about making the machines capable of understanding natural language in order to users can interact with machines in a more effective and faster way through natural language [32], [33].

NLP is a huge field that needs the analysis of different point of views to achieve processing a message, which can be said or written by a person. This is why, NLP has many aspects to study from a linguistic view [34] like phonologic, morphologic, and so on. Due to these aspects, NLP is composed of several levels of knowledge that vary according to different authors and time. In [35], the author recollected the nine levels of knowledge available in the literature: acoustic/prosodic knowledge (1), phonologic knowledge (2), morphologic knowledge (3), lexical knowledge (4), syntactic knowledge (5), semantic knowledge (6), discourse knowledge (7), pragmatic knowledge (8) and world knowledge (9). It is important to mention that using these levels depends on the domain of application. For example, a text translator only needs the levels 3 to 7 or 3 to 8. For our proposal, we will probably need the levels 4 to 6.

3. **Proposal.** We propose a system capable of answering questions that people would make through Social Networks using information from sensors connected to our system. Moreover, the sensors will have social capacities because the sensors will be able to have friends in order to answer peoples questions jointly. When a user will ask for specific information, the system will try to get the information from the registered sensors or from the relationship between sensors. For example, if a user asks for climate data the system will response with data from several sensors like temperature sensors and humidity sensors because these sensors have a friendship relationship based on the clime.

In order to explain our proposal, this section is composed by three different subsections: the registration of sensors, the socialization of sensors, the social interface and the connection of sensors to Social Networks.

3.1. **Registration of Sensors.** Our system needs the registration of sensors that can gather the data required to answer the questions made by people. For that reason, we propose that users could register sensors in a web application with the parameters that would allow us to identify the sensors properly. These parameters would be its location, its finality, its owner and the privacy state. Besides, some of those sensors would be used to refine the relationship between sensors as we will explain in subsection 3.2.

3.1.1. *Location.* The location will be a required parameter to register a sensor. The location will be composed by several locations because a sensor placed in one place will be reachable through different location levels. For instance, a sensor located in a university classroom would be reachable through different levels like University, City or Country.

This parameter will allow the system to know the neighbors of a sensor in order to allow the socialization between neighboring sensors as we will explain in subsection 3.2.

3.1.2. *Finality.* Another required parameter will be the finality. This parameter will indicate the role of the sensor. The finality will be composed by several finalities because a sensor could be useful for different proposes. For example, a temperature sensor would be handy for knowing the temperature but it would be also handy for knowing the climate conditions alongside other sensors.

This parameter is also used to allow the socialization between sensors with the same finality as we will explain in subsection 3.2.

3.1.3. *Owner.* The sensor owner will be another required parameter because the system will need knowing the owner in order to store and retrieve the sensors. This parameter will not be introduced by the user but the system will assign the owner considering the user who registers the sensor in the system automatically.

This parameter is also used to allow the socialization between sensors whose owner is the same as we will explain in subsection 3.2.

3.1.4. *Privacy State.* The privacy is very important when we handle data obtained from sensors [35] because we could use sensors that gather sensitive information like health problems, banking data or location data, which could be recollected automatically [36]. To ensure the privacy, the users will be able to specify different levels of privacy. Four privacy levels will be available in our system. Users will have to choose if their sensors are reachable by any user request, only by requests that include a specific location, only by requests made by its owner or a combination of the two previous levels.

Like the other parameters, this one would be also used to allow the socialization between sensors but it would be used not only to allow it but also to avoid it as we will explain in subsection 3.2.

3.2. **Socialization of Sensors.** The aim of our proposal is the creation of a network of sensors where they will have different types of relationships according to the parameters we exposed in subsection 3.1 in order to give certain information to the user when it asks something through a social interface. Available relationships will be based on the four previous parameters and they will be: neighboring relationship, working relationship, and familiar relationship.

3.2.1. *Neighboring Relationship.* Through a socialization based on neighboring relationship, sensors will be able to know the nearest sensors. This type of relationship will be used to set the different levels of privacy. One level of privacy will restrict the access to the sensor to only located requests.

For instance, if a user asks for the air quality of a building which is stored as location parameter of some sensors, the system will collect the information from sensors located in the building. Then, the system will combine all the gathered information and the system will send the information to the user.

3.2.2. *Working Relationship.* The primary relationship of the proposed system will be the working relationship. The aim of our proposal is to answer the questions, which had been asked by users through a Social Network, therefore, the system must have a way of recognizing what the user wants. This will be the finality parameter that we explained in subsection 3.1.2.

The working relationship will not affect the privacy but it will affect the system functionality. When a user asks for a certain information, the system will search sensors whose finalities are suitable to answer the users question taking into consideration all other relationships. Then, the system will combine all the gathered information and after, the system will send the information to the user.

3.2.3. *Familiar Relationship.* The familiar relationship will allow the system to know sensors which share their owner. This type of relationship will be also used to set the different levels of privacy. One level of privacy will restrict the access to the sensor to only requests from its owner.

For example, if a user asks for the humidity level without indicating the location, the system will collect the information only from sensors of the user which made the request instead of collecting the information from all public sensors that are suitable to answer the users question. Then, the system will combine all the gathered information. After this, the system will send the gathered information to the user.

3.3. **Social Interface.** One of our aims is the use of Social Networks to connect humans with sensors. We propose the use of Twitter as input interface through which the users will ask for information and the proposed system will answer.

Twitter is based on short messages composed by text and keywords that can represent users or topics. Our system will use these keywords to identify some parameters required to ask for information. The owner parameter will not be present in the text, in fact, it will be in the properties of the Twitter message because the owner will be the user of Twitter who makes the question. The rest of parameters will be find analyzing the text and hashtags. In order to identify the requested information, which is the finality parameter, the system will analyze the text and it will analyze the hashtags to find the location parameter.

Because of the use of Twitter, the system will have to store the username of sensors owners. This is why users will have to register in the web application using their Twitter profile.

Examples of use could be the next:

- **Asking for the temperature in New York City:** The system will consult all sensors registered in New York City and it will combine the information to send the appropriate value.
  - @*user*: @*senseq* What is the temperature of # *Shenzhen.*
  - @*senseq*: @*user* The temperature of # *Shenzhen* is $23°C$.
- **Asking where it is raining using users sensors:** The system will consult all users sensors and it will respond with the locations of sensors that return that it is raining.
  - @*user*: @*senseq* Where is it raining?
  - @*senseq*: @*user* It is raining in # *Beijing* and # *Shanghai.*

As we can see in the previous examples, the proposed system will require techniques to analyze and understand natural language in order to obtain what the user is asking for.

3.4. **Connection of Sensors to Social Networks.** In order to understand how our proposal will work, it is necessary to suggest an architecture that could interconnect sensors and Social Networks. We propose an architecture based on three interconnected layers as Figure 1 shows: **Social Layer**, **Backend Layer**, and **Object Layer**.

The first layer is the **Social Layer**. It will listen for messages on Twitter, whose receiver is SenseQ, and publish the messages that our system will generate in order to answer the users questions. Thus, the social layer will be the layer that will interact with the Twitters API.

The middle layer is the **Backend Layer**. It will process the messages extracting the parameters that will be needed to locate the objects that will be able to supply the required information. This layer will process and combine the information from the objects according to their relationships and generate the response for the users questions.

The last layer is the **Object Layer**. It will manage the connection with the different registered objects.

3.4.1. *Social Layer.* The Social Layer will be composed of two components: The Message Listener and the Message Publisher. The first component, the Message Listener, will be listening for messages continuously in order to collect messages whose receiver is SenseQ. This will be possible because Twitter provides an API that allows developers to listen for messages in streaming using different filters. The messages will be moved to the next layer, the Backend Layer, where they will be processed.

The other component, the Messages Publisher, will publish in the timeline of the system user the properly answer mentioning the user who made the question. The messages will come from the next layer, the Backend Layer, where they will be generated from the information that objects provide. The workflow of this layer will be the next:

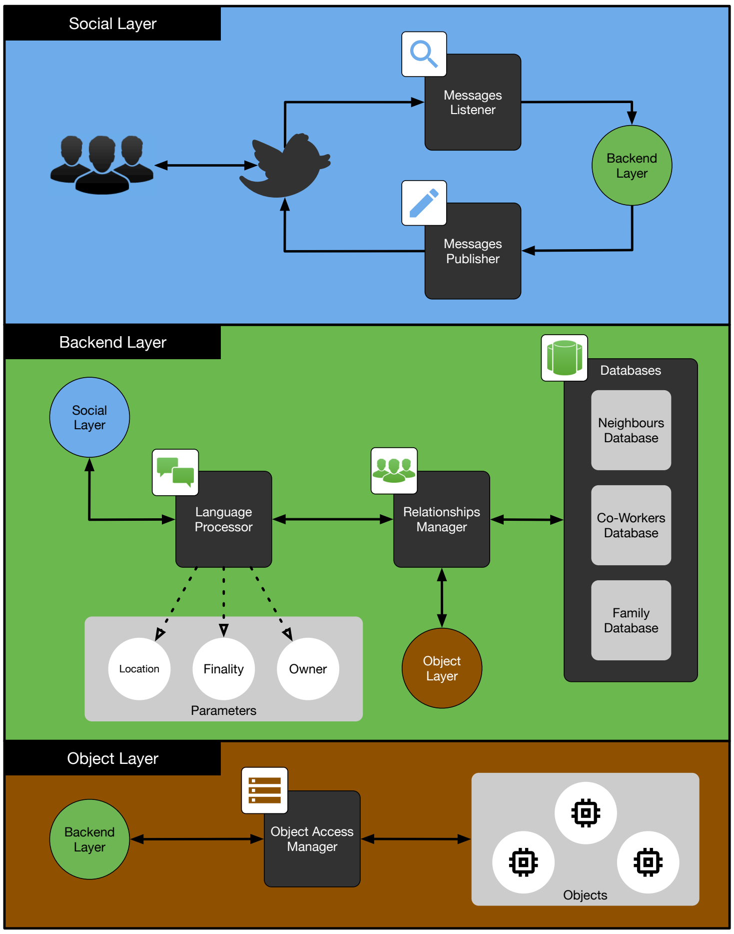

FIGURE 1. Three layer architecture.

1. Users will ask something to our system by posting messages on Twitter.
2. The Message Listener will collect these questions and it will move the questions to the Backend Layer, where the questions will be processed and answered.
3. The Messages Publisher will receive the answers to the questions made by users and after, the Message Publisher will post the answers to Twitter, mentioning the user who had asked.

3.4.2. *Backend Layer.* The Backend Layer will be composed of three components: The **Language Processor**, the **Relationship Manager** and the **Databases**.

The Language Processor will process the messages that arrived from the Social Layer in order to extract the parameters needed to classify the registered objects: the location, the finality and the owner. To obtain this information we will use NPL techniques that will allow us to extract the parameters from the messages. The parameters will be sent to the next component, the Relationship Manager. Moreover, this component will generate the answers to users questions that will sent to the Social Layer. To generate these answers, the Backend Layer will receive the required data from the Relationship Manager.

The Relationship Manager will search the objects in the databases according to the parameters extracted by the Language Processor. Thus, this component will search objects that have any type of relationship between them. For example, it will find objects with the same finality, objects which have a working relationship, objects with a close location and objects with a neighboring relationship. After, this component will merge found objects and filter them in order to discard the objects that not satisfy some parameter or relationship. Besides, the Relationship Manager will receive the data from found objects that allow the system to resolve the users questions. This layer will process the received data and sent it to the Language Processor.

The Databases component will storage the objects in three different databases, one per type of relationship. By this way, we will be able to find the objects that are related in some way. The best approach for implementing this component will likely be the use of graphs of relationships. The workflow of this layer will be the next:

1. The messages from Twitter will arrive at the Language Processor.
2. The Language Processor will process the messages, extract the three parameters and send them to the Relationship Manager.
3. The Relationship Manager will search the objects that are related according to the parameters extracted by the Language Processor in the Databases.
4. The Relationship Manager will access to the Object Layer in order to establish a communication with the found objects.
5. The Relationship Manager will receive data from the objects and merge the different data according to the relationships of the objects. After, this manager will process these data and send the processed data to the Language Processor.
6. The Language Processor will generate the messages from the data processed by the Relationship Manager and send the generated messages to the Social Layer in order to response users requests.

3.4.3. *Object Layer.* The Object Layer will be composed of two components: The Object Access Manager (OAM) and the Objects. The first component, the Object Access Manager, will handle the communication between the system and the objects. Through this component, the system will be able to collect data from the different registered objects and sent the data to the Backend Layer. The objects will be Smart Objects composed by some sensors in order to be able to collect data and establish communications through the Internet. We can consider two types of objects in the Internet of Things: Smart Objects and Not-Smart Objects [13]. Smart Objects are objects with intelligence and capable of running application. If they have capabilities to sense the environment, to perform actions or both, they will be composed of several sensors, actuators or both. In this case, we are interested in Smart Objects with sensors because we want to collect data that will allow us to answer users questions. Moreover, we will need that the objects can run applications because these applications will handle the communication with the Objects Access Manager through an API. Furthermore, SenseQ will have an applications generator to facilitate this step for people without knowledge about programming. The workflow of this layer will be the next:

1. The Object Access Manager will receive the instructions to establish a communication with the different registered objects.
2. The objects will be running an application generated by our system and they will collect data that they will send to the OAM when OAM will ask for them.
3. The Object Access Manager will receive data from the objects. After this, the OAM will send them to the Backend Layer.

4. **Conclusions.** In this paper, we have proposed a system that combines technologies of the Internet of Things and Social Networks in order to make easy the access to sensors data in real-time by users. For that purpose, we will use Natural Language Processing in order to understand and answer users questions with the data collected by sensors available in the Wireless Sensor Network that our SenseQ will use. Moreover, we have proposed three different types of relationships that filter the information that a user can access based on

the location, the finality, and the owner of each sensor. We have also explained how will work the communication with the system through a Social Network, Twitter, by using public messages that will contain hashtags and mentions. Finally, we have shown the proposed architecture based on three layers: The Social Layer, the Backend Layer and the Object Layer. Besides, we have explained how will work each layer. From this work, we will able to propose the next new future works:

- Adding new relationships based on owner friends: In this paper, we have talked about relationships between sensors, nevertheless, taking into consideration the relationships between users that use the system is another type of relationship that could be useful and we would study to integrate into our system.
- Establishing relationships between the system and users: Currently, we only use the Social Networks as a method of communication, but we would take the advantages of the Social Networks to establish friend relationships in order to, for instance, give automatically recommendations to users based on previous queries.
- External platforms: Our proposed is a standalone system that is not connected with other system and neither it allows the connection of an external system to retrieve information. A possible future work could be the creation of an API in order that other platforms or users can make queries to our system. Moreover, we could add to the system, platforms as the source of information like Midgar [18], [37]. In this way, the system could use other platforms as a sensor and retrieve information from them.

Acknowledgment. This work was performed by the “Ingeniería Dirigida por Modelos MDE-RG” research group at the University of Oviedo under Contract No. FC-15-GRUPIN14-084 of the research project “Ingeniería Dirigida Por Modelos MDE-RG”. Project financed by PR Proyecto Plan Regional.

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