WIRELESS SENSOR NETWORK AS A PART OF AN AGRICULTURAL GEOGRAPHIC INFORMATION SYSTEM

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In today's economy, it is crucial to optimize the resources used in agriculture, especially when the everyone goal is to get a high yield, with a higher profit, at a low cost as possible. Taking into account this context, the paper presents an architectural model for a Wireless Sensor Network, as a part of an Agricultural Geographic Information System, and describes the main components, the types of sensor used in this Wireless Sensor Network and three different ways to use them. In additional, ontology for Agricultural Geographic Information System is proposed, having the aim to offer a common view and to facilitate the understanding of the knowledge.

Keywords: wireless sensor network, precision agriculture, agricultural geographic information system, ontology

1. Introduction

Nowadays, precision agriculture faces and tries to find solutions to the following challenges:

- Maximizing the agricultural production by optimizing the distribution of seeds, nutrients and fertilizers, in variable doses, in order to obtain uniform plants growth, in one hand, and to compensate the unevenness of soil characteristics, on the other hand.
- Development and implementation of new technologies in the field of intelligent agricultural machinery for land cultivation, which offers a high degree of spatial accuracy.
- Automated data collection from the lands, in real-time, concerning the physical structure and chemical composition of the soil.
- Data storage in a structured database and then data processing, in order to support decision making.

The Wireless Sensor Network (WSN) comes to support precision agriculture, through its characteristics. A WSN consists of spatially distributed autonomous sensors to monitor physical parameters or environmental conditions,

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such as temperature, humidity, pH, etc. The sensors cooperatively pass their data through the network to a main location [1].

WSN, along with other technologies and tools like Global Positioning System (GPS), Capture Devices, Weather Station, etc. can be part of an Agricultural Geographic Information System (AGIS), which is a Geographic Information System designed for agriculture to capture, store, manipulate, analyze, manage, and present all types of geographical data [2].

2. Different ways to use sensors in agricultural lands

The WSN is built of "nodes" – starting from a few to several hundreds or even thousands. Each node is connected to one or several sensors. A sensor network node has typically the following parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting [3].

In Fig. 1 are presented three ways to use sensors in the process of collecting data from the agricultural lands.

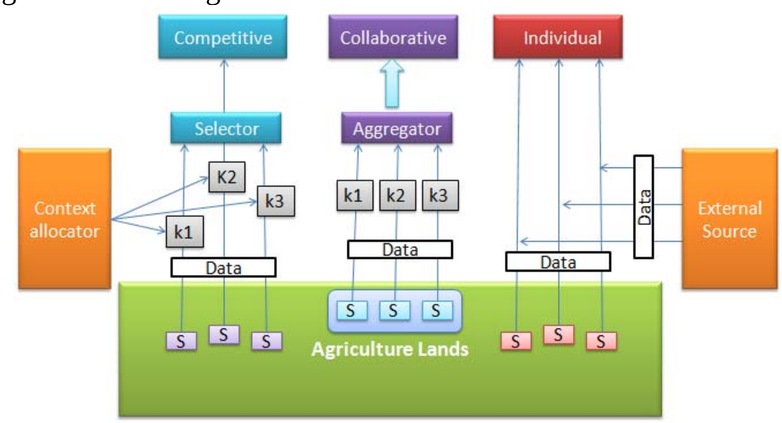

Fig.1. Three ways to use sensors in agricultural lands

The first case presents the competitive level of sensors. The utility of this competitive level is explained by the situation when the system needs to wait for the operator’s intervention, so maybe it becomes too slow. Thus the decision making capability can give large benefits, because new tasks can be allocated to suitable nodes using the context allocation. The role of Context allocator is to adapt the nodes behaviour in order to divide the workload based on operating or network conditions.

In the second case the sensors collaborate forming a network. Wireless Sensor Network has been deployed as a cost-effective communications technology that allows the data acquisition from the agricultural lands. This WSN consists of non-intrusive communication devices of small size, to which one or several precision sensors for data collection are adapted. Once the information arrives at their operators, it is further processed and analyzed in order to make the appropriate decision.

The third case presents the individual sensor usage. For instance, using the data provided by a moisture sensor and data coming from the weather station (external source), the farmer can set a daily schedule for soil irrigation, according to the soil moisture level and taking in to account the weather forecast. A soil moisture sensor will be connected to each zone, in the relevant regions in order to assess the humidity for the entire area. Thus the water consumption used for this purpose is minimized. If soil moisture at one time is already higher than the reference level, irrigation is not done in that area and so it saves water and energy, so it reduces costs.

3. Enabling the Wireless Sensor Network

SensorML (Fig. 2) is a representation of Extensible Mark-up Language (XML) used to describe the various aspects of the WSN, such as: sensor system description, the process model, chain processes, connections and the physical layout of the system [4].

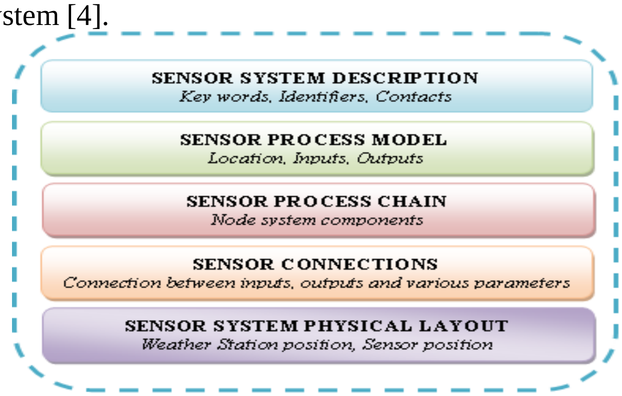

Fig.2. Sensor ML outline (adapted from Botts and Robin [4])

Sensor System Description describes the sensor purpose, the application field and the manufacturer using keywords, identification elements and contacts. **Sensor Process Model** describes the executable components of the sensor system, which includes inputs, outputs and other parameters measured (temperature, humidity, and pH, concentration level of nitrate, potassium and sodium of the soil).

In Fig. 3 is shown how the sensor process model provides information about data acquisition and the subsequent transmission of these data to AGIS, in order to support decision making process.

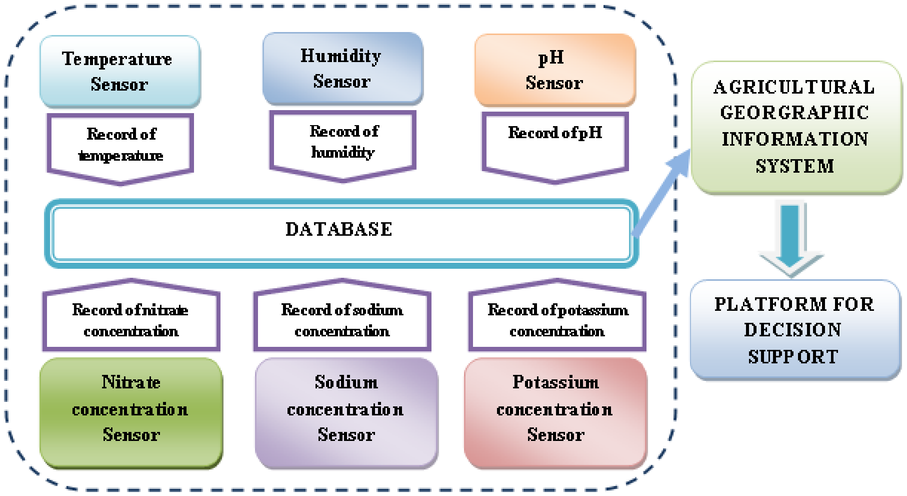

Fig.3. Sensor Process Model

Sensor Process Chain defines the execution methodology and explains details about each sensor: inputs, outputs, accuracy, minimum, maximum, mean, etc. **Sensor Connections** are part of the sensor process chain and define the connections between inputs, outputs and other specific parameters. **Sensor System Physical Layout** refers to spatial and temporal position of sensors and weather station.

4. Wireless Sensor Network Architectural Model

The Wireless Sensor Network Architectural Model consists of three tiers: Infrastructure Level, Communication Level and Physical Level, which are represented next, in Fig. 4.

Infrastructure Level includes Radio Control System, Data Storage Program and Database. Radio Control System is a system that uses radio signal to remotely control a device (e.g. sensors). Data Storage Program allows access and restores data by simplifying data management and protection, so it optimizes performance and reduces costs. Database organizes data collection to model relevant aspects of reality and to provide structured data like: parameters, min, max, mean, time.

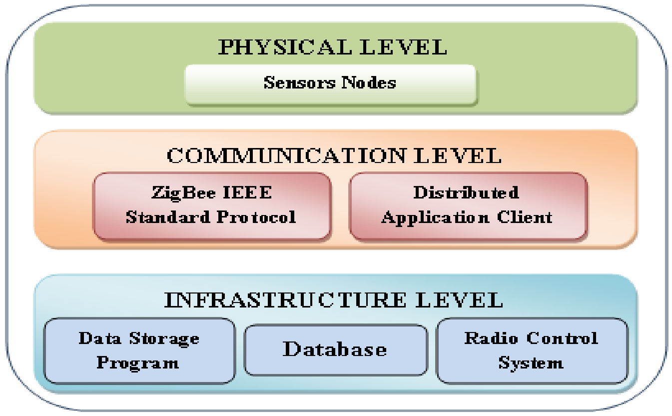

Fig.4. Wireless Sensor Network Architectural Model

Communication Level includes ZigBee IEEE Standard Protocol and Distributed Application Client. ZigBee is open standard protocol with no licensing fees, chipsets available from multiple sources, remotely upgraded firmware, fully wireless and low power, mesh networking to operate on batteries, low maintenance and larger network size with standard based high security. ZigBee is a specification for high level communication protocols. It is a typical wireless communication technology that uses low rate, low-power digital radios based on an IEEE 802 standard for personal area networks. The technology defined by the ZigBee specification is trying to be simpler and less expensive than other WPANs (Wireless personal area network), such as Bluetooth. ZigBee addresses radio-frequency (RF) applications that require a low data rate, long battery life, and secure networking and has a defined rate of 250 kbps best suited for periodic or intermittent data or a single signal transmission from a sensor or input device [5].

J. Garrett [6] has designed a Distributed Application Client that facilitates the visualization of data from sensors on the web by performing standard XML-HTTP. The application has the ability to locate the sensor using web mapping service (e.g. Google Web Map) and to visualize data at any given time, in a table or graphical form. Through Remote Procedure Call mechanism, requests and responses generated are processed. The response to a specified phenomenon consists of values grouped at specified time, with a statistical analysis that helps to identify changes in agro meteorological parameters, but also to detect sensor faults [7].

Physical Level refers to sensor nodes from the Wireless Sensor Network.

A sensor node is a node in a wireless sensor network that is capable to perform some processing, gathering sensory information and communicating with other connected nodes in the network [8]. The main components of a sensor node are: one or several sensors, microcontroller, transceiver, external memory and power source (Fig.5.) [9].

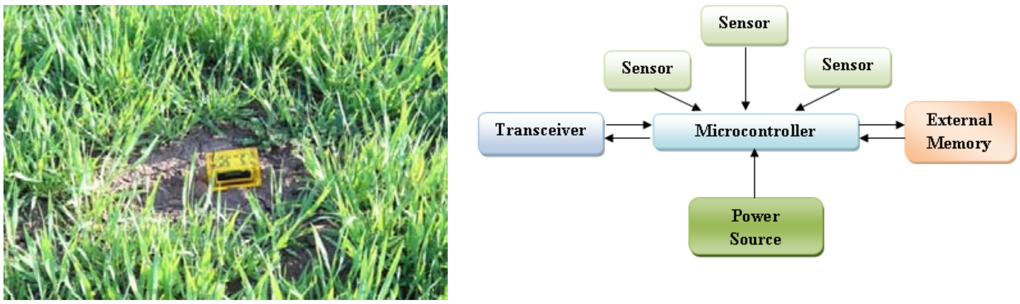

Fig.5. (a) Wireless Sensor placed in the field; (b) Components of Sensor Node

The main controller function is to perform tasks, processes data and controls the functionality of other components in the sensor node. The transmitter and receiver functionalities are combined into a single device known as a transceiver and radio frequency-based communication is the most relevant for WSN applications. Regarding the memory, flash memories are used due to their cost and storage capacity. The power source is often a battery. Wireless sensor networks have generated a lot of research during the past decade. Their main challenge is designing robust and low power devices for a long period of time. Because they are battery powered, optimizations in data processing and data transmissions are needed to enhance the lifetime and throughput of the network [10].

5. Wireless Sensor Network – experimental results

In order to validate the WSN operation in the field, a number of 16 sensor nodes were placed in an agricultural crop, at a distance of 20 m. The farmer is able to see their operation directly in the vicinity of the crop, using a WSN gateway and a computer, as it is shown in Fig. 6.

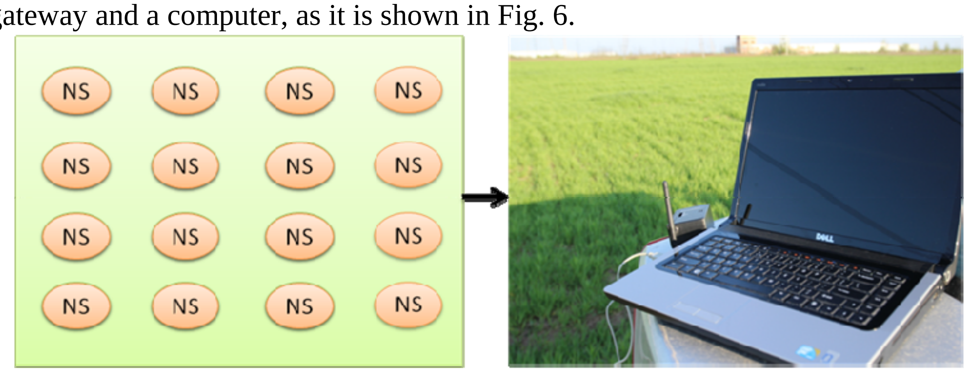

Fig.6. Testing the Wireless Sensor Network operation

Table 1 presents the measured values for humidity parameter, by three sensor nodes, for a period of 1 minute. As it can be seen, according to their placement, the sensor nodes return different results one from other. But a sensor node return each time, mostly the same result, having small variation.

Table 1

Experimental results

Id	DAY	Hour	AM/PM	parent	voltage	humid	humtemp
5	05/25/2013	10:17:16	AM	0	3.2029	35.3	26.5
12	05/25/2013	10:17:16	AM	5	2.7707	42.8	23.5
11	05/25/2013	10:17:19	AM	12	2.1262	34.5	22.82
5	05/25/2013	10:17:24	AM	0	3.2029	35.3	26.46
12	05/25/2013	10:17:24	AM	5	2.7707	42.7	23.52
11	05/25/2013	10:17:27	AM	12	2.119	35.7	22.79
5	05/25/2013	10:17:31	AM	0	3.2029	35.3	26.48
12	05/25/2013	10:17:31	AM	5	2.7707	42.9	23.51
11	05/25/2013	10:17:34	AM	12	2.1262	33.5	22.84
5	05/25/2013	10:17:39	AM	0	3.2029	35.3	26.44
12	05/25/2013	10:17:39	AM	5	2.7707	42.9	23.52
11	05/25/2013	10:17:42	AM	12	2.119	34.8	22.82
5	05/25/2013	10:17:46	AM	0	3.2029	35.3	26.42
12	05/25/2013	10:17:47	AM	5	2.7646	42.9	23.53
11	05/25/2013	10:17:49	AM	12	2.1262	32.3	22.89
5	05/25/2013	10:17:54	AM	0	3.2029	35.4	26.45
12	05/25/2013	10:17:54	AM	5	2.7707	42.9	23.54
11	05/25/2013	10:17:57	AM	12	2.119	33.8	22.85
5	05/25/2013	10:18:01	AM	0	3.2029	35.4	26.48
12	05/25/2013	10:18:02	AM	5	2.7646	43	23.54
11	05/25/2013	10:18:05	AM	12	2.1226	31.1	22.92
5	05/25/2013	10:18:09	AM	0	3.2029	35.4	26.51
12	05/25/2013	10:18:09	AM	5	2.7646	46.7	23.62
11	05/25/2013	10:18:35	AM	12	2.1226	28	22.99

6. Wireless Sensor Network within Agriculture Geographic Information System Ontology

The ontology has been developed with the aim to offer a common view and to facilitate the understanding of the knowledge (concepts and relations) regarding the Wireless Sensor Network and Agricultural Geographic Information

System. The proposed ontology was built using Protégé-OWL Editor, using OWL Full version. Protégé is free tool that uses OWL and other languages to built ontologies [11].

The Web Ontology Language (OWL) is one of the most known languages for creating ontologies. This language can be used along with information written in RDF [12].

The Resource Description Framework (RDF) is used for conceptual description or modelling of information that is implemented in web resources, using a syntax notations and data serialization formats [13].

OWL Full is appropriate choice for the ones who need maximum expressiveness and the syntactic freedom of RDF, with no computational guarantees [14].

Fig. 7 illustrates an excerpt the developed ontology using Protégé, namely the general representation of Agricultural Geographic Information System and the relations between its components, in which the Wireless Sensor Network is a part

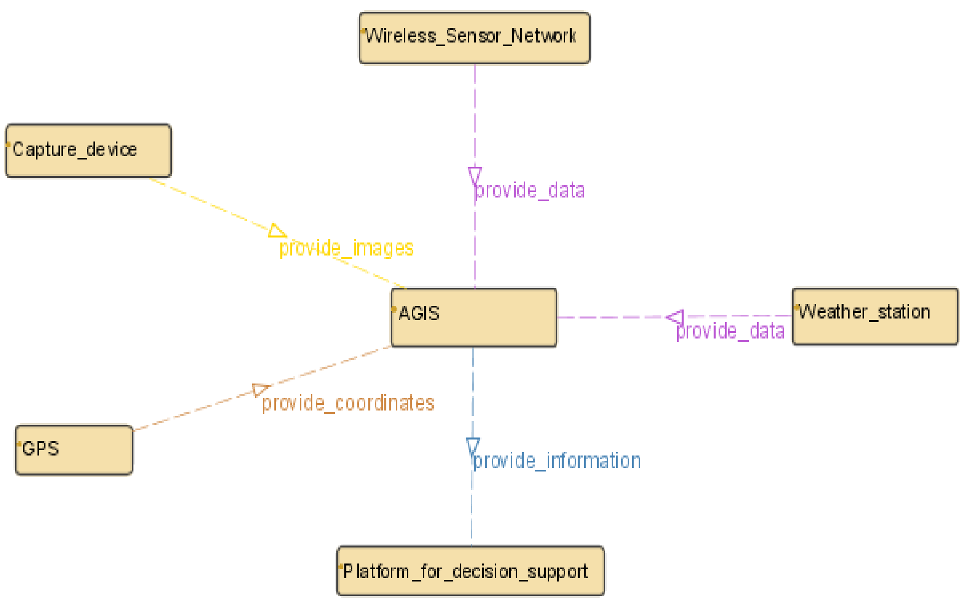

Fig.7. General representation of Agricultural Geographic Information System in Protégé

In Fig. 8 is shown the Wireless Sensor Network ontology representation in Protégé.

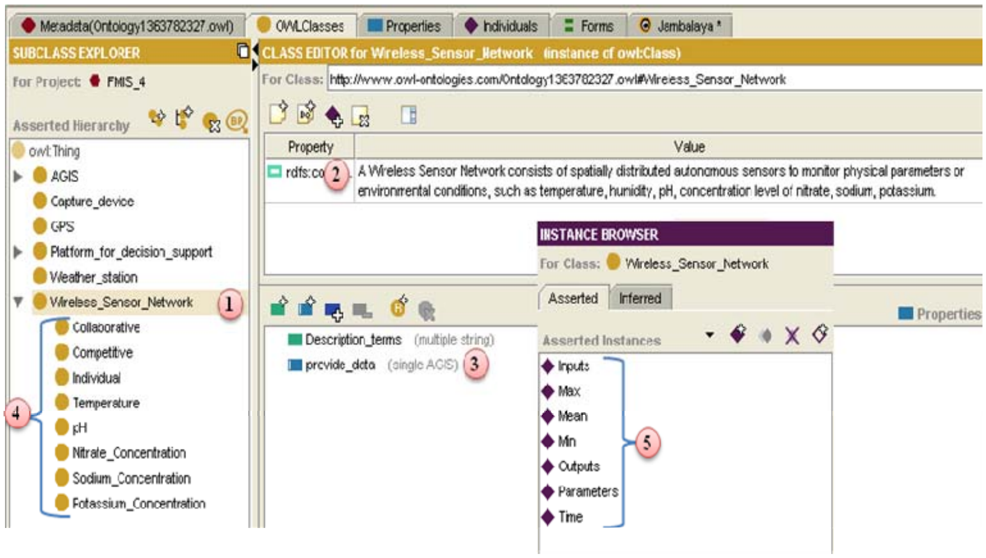

Fig.8. Wireless Sensor Network representation in Protégé

Wireless Sensor Network is a class (1) in the developed ontology, and has a term description (2). The property of WSN is to provide data (3) to Agricultural Geographic Information System. The WSN has 8 subclasses (4) representing the types of sensor used in agricultural lands, as they were previously present in Fig. 1 and Fig. 3. For this sensors have been define specific instances, which are presented in the capture marked with bullet (5).

7. Decision Making Process within the Farm

The information provided by the Agricultural Geographic Information System is used for Decision Making Process. The Decision Making Process represents the process of selecting a logical choice from the available options. In order to make a good decision, the farmer must weigh the positives and negatives of each option, and consider all the alternatives. Considering all this issues, the process of decision making within the farm, will follow seven steps, presented below [15]:

1. Gather the relevant information.
2. Identify the context and nature of the decision to be made.
3. Identify the possible alternatives and the criteria for evaluation.
4. Evaluate the alternatives based on the identified criteria.
5. Choose among alternatives.
6. Take action.
7. Review decision and consequences.

Fig. 9 presents the decision making process within the farm.

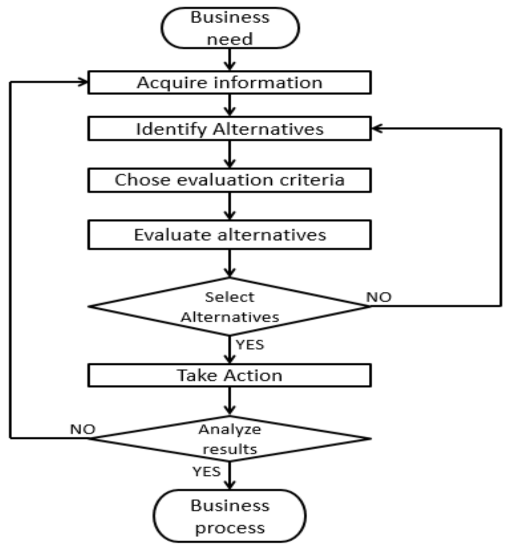

Fig.9. Decision Making Process within the Farm

The process starts with gathering the information needed in the next step – decision identification. In order to make the best decision, the farmer must identify, search and choose among all the available alternatives.

The Agricultural Information System structures data acquired from sensors and combines it with relevant information provided by web services in order to support the following steps: information gathering identify alternatives, identify criteria for evaluation.

The next step is dedicated to the alternatives evaluation in terms of advantages and disadvantages. The evaluation is repeated until finding the best solution. Then, the farmer takes action and, if the step of review decision and consequences confirm the proper decision, the process will end. If not, the process will be repeated starting from the information gathering step.

8. Conclusions

Wireless Sensor Network represents a real support for precision agriculture. Through its characteristics, it is able to monitor many parameters that must be measured in the agricultural lands (temperature, pH, humidity, soil concentration level for nitrate, sodium, potassium).

The manager or the final user is able to have access to information or to statistical analysis, based on data acquired from WSN, in order to optimize the resources consumption, and so reduce costs.

The paper presents an architectural model for a Wireless Sensor Network, consisting of three levels: Infrastructure Level, Communication Level and

Physical Level, which are explained in detail in chapter 4. Different types of sensor used in agricultural lands are presented, together with three different ways to use them.

The functional operation of the Wireless Sensor Network was tested for the parameter humidity, and the experimental results were presented in chapter 5.

In order to offer a common view and to facilitate the understanding of the knowledge (concepts and relations) regarding the Wireless Sensor Network and Agricultural Geographic Information System, ontology has been developed, Protégé-OWL Editor..

The authors proposed a Wireless Sensor Network as a part of an Agricultural Geographic Information System, having the property to provide accurate data for the system of which it forms part, and so it becomes an important tool in decision making process, whose steps were presented in chapter 7.

9. Future work

As future work, authors will take into consideration:

- Standard definition for Wireless Sensor Network Architecture;
- Ontology definition improvement in order to handle different aspects related to interoperability;
- Integrate all the presented information systems elements in a platform able to give direct support to managers for decision making process;
- A Case Study implementation addressing all these future features.

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