A ROADMAP FROM INTERNET OF THINGS TO INTELLIGENT AGRICULTURE AND WoT

Li Li[2], N. Sigrimis[1], A. Anastasiou[1], M. Wang[2] and V.C. Patil[3]

[1]Prog Agricultural University of Athens

[2]China Agricultural University

[3]King Saud University

ABSTRACT

With the development of sensing, wireless communication, and Internet technologies, we are now living in a world that is filled with various smart things—the Internet of Things. This paper introduces and prospects an emerging research area—the Embedded Intelligence (EI). This field aims at revealing the individual behaviours, spatial contexts, as well as social patterns and urban dynamics by mining the digital traces left by people while interacting with Internet of Smart Things (cameras, smart cars, smart cards, etc.). In the agricultural sector we add mining of existing technology (books, articles, blueprints) to generate high deth Ontologies for reasoning and making pro-active decisions. We further include Intelligent Data Analysis to discover new knowledge from data records. The paper discusses the research history, characteristics, general architecture, major applications, and research issues of EI and exemplifies an application of the team in IOT Smart Irrigation.

The purpose of presenting it as a TRM (Technology RoadMap) was to clarify the challenges and opportunities in the general area of "intelligent building technologies" (IBT) and more specifically to smart greenhouses, smart irrigation, or smart crop management, fulfilling the requirements of SCPI objective set by FAO. The understanding of smart agriculture is important to be identified by the scientific community as a significant issue because it is needed for nations to develop and adopt these emerging technologies. Global interoperability is of key importance, and so it is a common understanding of values such as privacy and security, based on open, fair and transparent international standards.

Keywords: *Internet of Things, Ubiquitous Computing, Embedded Intelligence, Precision Irrigation, Deficit Irrigation.*

1. INTRODUCTION

The Technology Roadmap (TRM) concept is a consultative process that is designed to help industry, its supply-chain, academic and research groups, and governments come together to jointly identify and prioritize the technologies needed to support strategic R&D, marketing and investment decisions. These technologies will be of critical importance to an industry in the next five to ten years. In agriculture we could state it is presently needed to face the hunger of people and the global competition. Manufacturers, transportation businesses, logistics firms, food and energy companies, and other enterprises across Europe are employing radio frequency identification (RFID) to cut costs, enhance visibility, improve asset-utilization rates, streamline business processes, improve inventory accuracy and achieve many other benefits.

1.1 IOT History Base

Historically, the Internet of Things-IOT, is a concept wherein objects are uniquely identified by barcodes, RFID tags, etc. During the physical object lifecycle, event readings are made using sensors (RFID and NFC readers, cameras, scanners, GPS/GSM/Wi-Fi, manual reading, etc., collected and recorded in databases, and further aggregated, consolidated or merged with other information already handled in computer systems for traceability, logistics, management or sales issues. The original idea of the Auto-ID Centre is based on RFID-tags and unique identification through the Electronic Product Code. The next generation of Internet applications using Internet Protocol Version 6 (IPv6) would be able to communicate with devices attached to virtually all human-made objects because of the extremely large address space of the IPv6 protocol. This system would therefore be able to identify any kind of object.

A combination of these ideas can be found in the current GS1/EPCglobal EPC Information Services (EPCIS) specifications. This system is being used to identify objects in industries ranging from Aerospace to Fast Moving Consumer Products and Transportation Logistics.

1.2 On the Definition

Can we define the Internet of Things in a way that is concise, clear, general, but specific enough to be comprehensive? The question of the precise definition of the IOT has created considerable intellectual debate in recent years. Getting the definition perfect is important for regulatory, legal, legislative and scientific purposes. Several presentations at the European Commission and exchanges on a mailing list continue the debate yet.

The definition proposed by *Monique Morrow* of Cisco, suggests (1): "The Internet of Things consists of networks of sensors attached to objects and communications devices, providing data that can be analyzed and used to initiate automated actions. The data also generates vital intelligence for planning, management, policy and decision-making."

Olivier Dubuisson of Orange FT Group defines Internet of Things as: "A global ICT infrastructure linking physical objects and virtual objects (as the informational counterparts of physical objects) through the exploitation of sensor and actuator data capture, processing and transmission capabilities. As such, the IoT is an overlay above the 'generic' Internet, offering federated physical-object-related services (including, if relevant, identification, monitoring and control of these objects) to all kinds of applications."

In my opinion, the IoT definition should not specify the purpose. It must describe only what it is, and in that sense I agree with Monique as it is concise, clear and comprehensive but to be a little more general (as it should) I would avoid the necessity of networks (it may be only one connected to the internet) and no sensors (it may not be a sentient environment but just an RFID), so I would state that: "*The Internet of Things consists of devices attached to objects and communications devices, providing data on the Internet that can be analyzed and used to feedback or initiate automated actions*". This includes the widely accepted form of a simplest RFID, the IOT generic technology (Sigrimis 2008) but also can be as big as a whole Industrial computer connected with wires to the internet. I think the expression for "The data also generates vital intelligence for planning, management, policy and decision-making" refers to the purpose, and is synonymous to pervasive communications or to the SED (=Speaking Electronic Devices), as we named such IOT predecessor in the 90s. It is also referring to the exploitation of the data that is of course a necessity for adding value to IOT but it is not necessary for the IOT characterization. Of course the fact is that the definition probably will need frequent updates to reflect the evolution of the state of the art, but the "simplest the more lasting", until the time technology has matured enough to need no definitions or end the debate.

Ierapetra Crete ***! SAVE WHEN YOU HAVE IT TO HAVE IT!***

1.3 On the Progress

The research area that was opened with IOT is enormous, ranging from Technologies and concepts in modern networked things, to Emerging IOT business models and process changes. Further onto the "Smart Objects" that is supported by Embedded Intelligence, a never ending subject as it will need to catch human intelligence, which has no time limit ever.

I was asked first in the 80s to participate in AI applications for agriculture. My answer was as such: "it is not possible to contribute much in this field because AI is not mature yet in its generic field". Today I am happy to alter the answer of the 80s and declare that we need a technology like IoT as the enabler for exploitation of knowledge at field level, or as said, "from the research lab to the root of the plant"-Geomations Logo. In ecosystems natural creations such as streams, rivers, coastal wetlands, grasslands, and forests provide numerous services that fundamentally support human health and well-being. These also need protection from climate change and human activity likewise the production agriculture.

The importance of electronics in the modern world is hard to overstate, touching every aspect of life. A good example is the evolution of telephone followed by Tablets that offer productivity tools for enterprises, healthcare institutions and governments, enhancing communications and providing a mobile communications work platform. Telecommunications offers a striking example of the rapidity of the electronics revolution. The move from 1G to 4G took a full decade but the time to 5G and 6G will be much shorter with more plentiful of services.

2. STATE OF THE ART

2.1 IPv6

With the growth of IP connected devices the Internet is exhausting the currently used IPv4 address protocol (of only 3.4 Billion unique addresses). Service providers anticipate that they will no longer have access to additional IPv4 addresses beginning 2013. Geomations SA (our spinoff company) follows this wave to "empowered by IPv6" with a new connectivity design which will connect all different equipments to the Internet and will have contributions with cloud services for its customers but will also contribute with embedded intelligence content. We are starting operating experimental IPv6 networks in private networks and will try seamless transition from IPv4. We have joined our efforts with our Chinese colleagues to actively deploy technologies to support IPv6 addressing. We're in the process of IPv6_ready IOT Consumer products and prepare a full range of Agricultural Business Services (WOT) with IPv6 capabilities, so we will be ready to support IPv6 as the industry adopts it. IPv6 adoption is critical to all nations as the investments for infrastructure growth must continue with next generation capabilities. A smooth transition to the new protocol across each nation and in sync with the globe is a necessity.

2.2 6loWPAN

Well-established fields such as control networks, and burgeoning ones such as "sensor" (or transducer) networks, are increasingly being based on wireless technologies. Most (but certainly not all) of these nodes are amongst the most constrained that have ever been networked wirelessly. Extreme low power (such that they will run potentially for years on batteries) and extreme low cost (total device cost in single digit dollars, and riding Moore's law to continuously reduce that price point) are seen as essential enablers towards their deployment in networks with the following characteristics:

- Significantly more devices than current local area networks
- Severely limited code and ram space (e.g., highly desirable to fit the required code—MAC, IP and anything else needed to execute the embedded application-in, for example, 32 K of flash memory, using 8-bit microprocessors).

A chief component of these devices is wireless communication technology. In particular, the IEEE 802.15.4 standard is very promising for the lower (physical and link) layers. As for higher layer functions, there is considerable interest from non-IETF groups in using IP technology. The IEEE 1451.5 standard for wireless transducers has a chapter for 6LoWPAN and the ISA SP100 standard for wireless industrial networks has adopted 6LoWPAN for their network layer.

2.3 Web Semantics

The Semantic Web technologies could, in theory, extend the search capabilities. Today, they allow to structure in a formal way the information published on the Web as metadata. This way of structuring can give contextual sense to published information and can be handled automatically in search engines or in exchanges between applications.

Reusing and adapting current Web technologies would allow anybody to automatically publish or search object-related information guaranteed to be directly usable and significant. This association, of semantic web technologies with the Internet of Things defines what will be the "Web 3.0.

All current approaches and proposed technologies rely on one or more pre established organization model: EPCGlobal, for instance, targets exhaustibility and universality for some businesses (automotive, aeronautics, pharmaceutical, etc.).

2.4 Web of Things

The Web of Things is an inspiration from the Internet of Things where everyday devices and objects, *i.e.* objects that contain an embedded device or computer (*i.e.* MACQU), are connected by fully integrating them to the Web. Examples of smart devices and objects are wireless sensor networks, ambient devices, household appliances (*i.e.* speaking refrigator), RFID tagged objects, etc.

Unlike in the many systems that exist for the Internet of Things, the Web of Things is about re-using the Web standards to connect the quickly expanding eco-system of embedded devices built into everyday smart objects. Well-accepted and understood standards and blueprints (such as URI, HTTP, REST, Atom, etc.) are used to access the functionality of the smart objects. Reusing and adapting current semantic web technologies in the *Internet of Things* would allow anybody to automatically publish or search object-related information guaranteed to be directly usable and significant. Possibly this association defines what will be the "Web 3.0", but we will need new approaches to succeed. Although things are not clarified yet we can define Web 3.0 as the conjunction of the Internet of Things with the Semantic Web.

Today, IOT applications only fit the requirements of closed or semi-open loops or value chain management. Each implementation is isolated and cannot easily interoperate with others. We'd rather speak of a set of *"Intranet of Things",* since using the term Internet is improper (we also give an example below of a closed loop for irrigation management in an intranet of the Flow-Aid consortium). However the primary ambition of the IoT is to publish these event related information on the Internet, in order to allow all actors involved with object manipulation or use to access them.

A number of techniques and standards have appeared with the aim of publishing and retrieving this information, some of which are inherited from the existing Internet static resolution systems: ONS—Object Naming system—derived from DNS by the MIT and adopted by EPCGlobal. Other solutions allow for a more dynamic search, like what Google proposes on the Internet: a search engine that exhaustively indexes keywords found in natural language on the Web and manages to actually find (part of) the information looked for.

2.5 Smart Objects Building the Internet of Things

Radio Frequency Identification (RFID) technology allows automatic identification of objects with the help of a small electronic chip (Sigrimis 1985). The data stored on this "smart tag" can be read by wireless devices, called RFID readers that transfer to the Internet or to an Intranet, and may contain other monitoring variables forming a sentient environment that allows high resolution management (Sigrimis 1986).

IOT develops to an enormous number of smart tags interacting with and transmitting information to each other and with decentralised and central systems. Imagine real world objects being identified by RFID and having an individual digital presence. This future dimension of technologies like RFID with a registration of every item, traced or serviced anywhere, is the Internet of Things (IOT). Combined with GPS and mobile networks give us the capability for RTLS (Real Time Location Systems) as well as Sentient Environments. This together with Embedded Intelligence give us the potential for the upper level of automated high resolution management. If embedded intelligence refers to agricultural crops then we will be able, using IOT, to create web services WOT (mainly on the cloud due to volume requirements) to balance our cropping actions according to SCPI concept of FAO.

3. METHODOLOGY-AGENTS-WOT AND ONTOLOGIES

3.1 Web Intelligence

Regarding the Internet of Things, how to give objects some kind of software intelligence so that they can be able to act, react, "preact" or operate according to the context.

The only way to succeed is to assess the sensor-generated information -retrieved from RFID, barcodes, GPS, cameras, etc. to make sense in the context of the actor's end goals and purposes at a specific time, whoever is the actor: people, web services, objects, etc. We then must admit that objects (*i.e.* greenhouses) can have goals. Therefore, giving an event a meaning is, before anything, focusing on the context of pursued objectives at a given time: *i.e.* a recorded low soil moisture must refer to the specific plant tolerance and salinity response, *specific time* or better the stage of development or even if at flowering we need to maintain a higher water soil availability (what Sigrimis calls URDI-Ultimate Regulated Deficit Irrigation that is based on the "exact context of the plant" and this requires detailed knowledge of plant responses to its environment).

So a Semantic web useful for the Internet of Things is not so much trying to create links between ideas or words (semantics) but to be able to interpret the meaning of an information in a *precise context:* "what, where, when, how" and most importantly "why". This requires a local autonomy in terms of perception, analysis, know-how and decision. In other words, we must put some intelligence at the lowest level (principle of subsidiarity). In the agricultural sector (Figure 1) we seek not just the business operations but more deeply we need know the crop needs and arriving in optimal decisions with high resolution management. We present in the Irrigation Case a minimum of shallow knowledge (subsidiary) that is based on expert knowledge as well as a second level of intelligence that is based on encoded scientific knowledge (deep Ontologies, response or demand models etc.) as well as knowledge discovery with Embedded Intelligence. The first level *expert* (shallow) knowledge is at later stages, when the deep section is fully developed, not useful because the deep section empowers higher resolution but in some instances is a necessary component for dissolving conflicts or ambiguities or choosing a reasoning pathway.

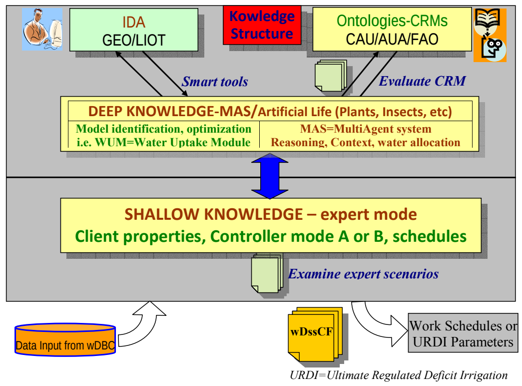

Fig. 1: Knowledge Structure Organization Suggested for Agricultural Applications

On the existing Web, the smart actors are human beings and their social networks: this is the underlying concept of Web 2.0 as a distinction from Web 1.0. Making *objects* true actors on the Web (3.0) is no more than giving them enough autonomy and intelligence, suited to the roles we want them to play. In another research effort of my team we try to create avatars of insects *i.e.* we use Multi-Agent system to represent the life of a whole greenhouse system (the plants, the insects, the human requirements, the physical structure, etc.) and thus be able to apply Integrated Pest Management or even Integrated Crop Management. We need to have live digital insects to estimate risk of an infection and take pro-active actions to defeat the real counterpart (Figure 2).

Internet is ubiquitous—especially through mobile technologies—and enables us to deport intelligence on different computers. We then can associate intelligent avatars—software objects—to each physical object. Such avatars are virtual and independent software components, like "web services" and can be hosted on "cloud like" infrastructures, centralized servers, personal computers, smart phones, etc. Accordingly, the objects, through their avatars, interact and interoperate together or with other actors of the Web. By gradually increasing the level of avatar's intelligence, we then reach ubiquitous or pervasive computing, as IOT practitioners we often draw out. In order to do this, we need design methodologies and tools for software objects conception and the patterns and naming standards (EPC, IPv6, URI, etc.). Finally, these design methodologies should be able to integrate and facilitate the generation of new services or practices: managing physical objects anywhere, anytime, anyhow; promote their reuse or sharing and facilitating the knowledge.

3.2 Embedded Intelligence

With the advent of pervasive computer applications, the bandwidth proliferation of heterogeneous wired and wireless communication networks and the new wave on low cost environmental sensor networks have created massive collection of data while security and trust issues are yet of an obstacle. Rapid advances in sensors, web data collections and algorithms continue to fuel dramatic needs for data mining and intelligent processing. Data mining methods, enabling e-science (ANNs, Bayesian networks, decision trees, support vector machines), are becoming mature and will be used in new research for a novel way of data analysis (*i.e.* e-irrigation). Soil sensors (Water-mark, TDR, WET, SM200, flow-aid ceramic, etc.) are recently advanced, and a big variety in cost and performance exists to select from, for each application. The advent of WSN is at a stage to convince that such sensor networks are already practically possible and, while Internet for everyone has become already a reality (*i.e.* Geomations Remote Support, through a single Satellite link and a terrestrial wLAN, or mobile internet offered by telecom companies) at a monthly cost that allows to collect data for irrigation scheduling < http://www.flow-aid.wur.nl/UK/ > project). The quest in businesses, and the main objective of new research, is to gain advantage of "IoT technology everywhere", which leads to (agri)-business intelligence. The hallmark of this new direction on knowledge discovery and exploitation is "*data analysis to discover knowledge to improve decision making (for example e-irrigation, under Intelligent soil sensor)*".

Although many Intelligent Data Analysis (IDA) systems have been developed (*i.e. K.wiz* of Thinkanalytics, *Intelligent Miner* of IBM, *Alice* of isoft, etc.) most "big data" libraries remain unexploited. In science, and engineering, enormous amount of data have been generated. Molecular biology has created huge data banks and some exciting successes have been announced in bio-informatics out of data processing in protein sequencing. In soil-water-plant interactions a model may consist of many differential and non-linear algebraic equations as well as non-algebraic qualitative (decision trees) relations. Model building and model scalability are critical issues that need be addressed by the analysis of data of even a simple soil sensor.

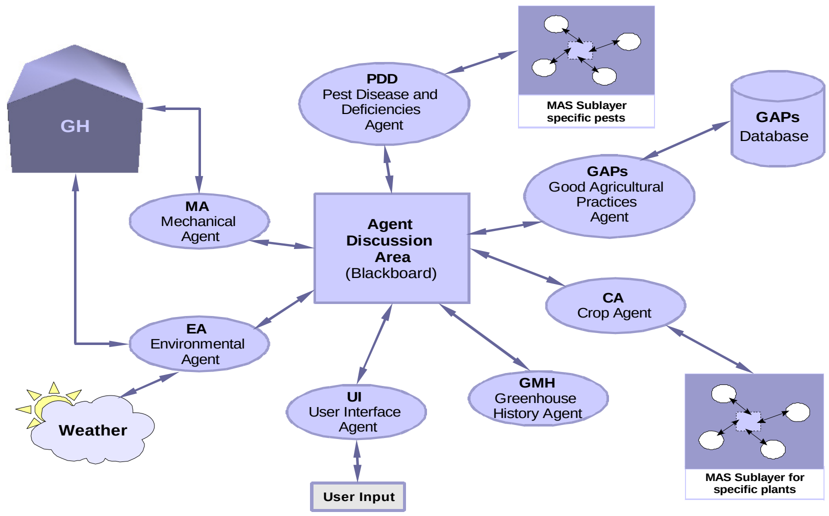

Fig. 2: Overall Pictorial of Green-MAS

Embedded Intelligence appears in two forms:

1. Encoded existing knowledge. To be useful it must be taken from knowledge repositories (books, articles, blueprints, expertise), the best form being Models (a description of processes that has been generalized from experimental scope to a working scope and validated) and transformed to structured Ontologies (7) that have depth to allow reasoning and estimation so decisions can be based upon. ….
2. Algorithms (data mining) that can analyze data records (or transrecords for nulti-variable analysis) and identify Models (maintenance of Knowledge) or transform data to supporting processes and identify missing properties or parameters of a grey system. There are a considerable number of Intelligent Data Analysis tools (ANNs, GAs, fuzzy models, SVMs (8), assisted by powerful methods like gradient descent back propagation, machine learning methods, etc.) and create evolving systems that become smarter every day or growing up artificial life (avatars etc.), with a lately upcoming technology the Agents style of programming that can encompass all said modern computer capabilities).

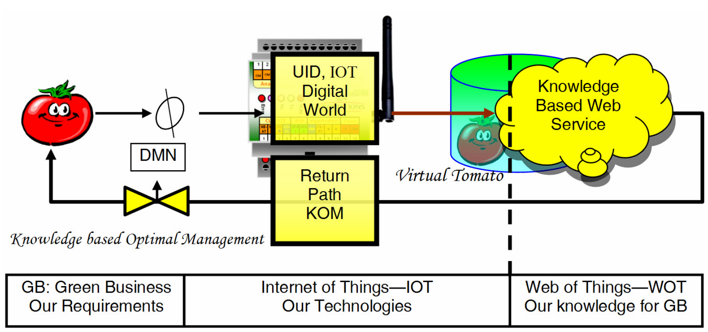

Fig. 3: IOT—WOT Model for Green SCPI Agricultural Business

4. A CASE APPLICATION

Optimal operation of commercial fertigation systems depends mainly on the appropriate management of the available water sources, especially under saline conditions, as well as the optimal management of nutrient supply. The system, developed under FLOW-AID (an FP6 project), is a water management system that can generally be used at farm level in situations where the water availability and quality is limited. This market-ready precision irrigation management system is focused on new hardware and software. The hardware platform delivers a maintenance-free low cost dielectric tensiometer and several low-end irrigation or fertigation controllers for serving various situations.

Besides improving irrigation delivery systems, an important effort must be addressed to *improve water management at the field level.* Unfortunately, irrigation schedules are chosen arbitrarily very often in South water scarcity in European countries. Efficient irrigation schedule should be based on evapotranspiration rates, performing a simple water balance, or on root zone sensors. This proposal embraces the following FAO position:

FAO: Sustainable Crop Production Intensification (SCPI) responds to the need to increase the opportunities for crop production to address the current and future environmental threats the world is facing, and ultimately respond to the need to increase food production for the forecasted increase in human population. Hence, an important aspect of SCPI is that it looks to manage biological processes sustainably to optimize crop production.

4.1 Flow_Aid FP6

All the actors involved in the irrigation sector, from farmers to equipment manufacturers, share the social and political pressure to make sustainable use of resources. Advances in agronomic research proposed irrigation-sector businesses the need to move beyond the current water use practice in Open field crops. We must change the highly user dependant irrigation management (with limited clock-based controllers or manual or remote mobile telephone control, product-oriented approach) and evolve towards using crop monitoring tools (IOT), remote services and information and communication technologies (service-oriented approach) with a system that can be easily retrofitted to existing installations.

Fig. 4: IOT Application in Lettuce Production with WOT Restricted to Fertigation Management

Results on Case (data collected by PRI experiments of Flow-Aid coordinated by Dr Balendonck)

Data recorded in comparison with conventional practice revealed the potential to saving 7% water, while improving yield by 5% and high resolution fertigation management **diminishing drainage to 0%!** (a necessity for Dutch fields by state regulations).

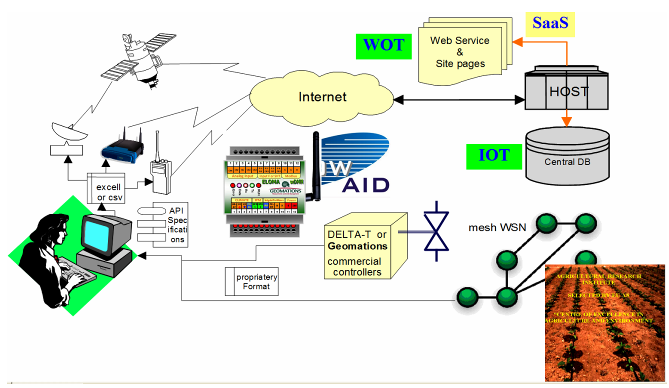

Fig. 5: Flow-Aid Implemented IOT-WOT Automatic Closed Loop Operation

5. CONCLUSIONS-RECOMMENDATIONS

5.1 Intelligent Agriculture

The importance of intelligent data analysis arises from the fact that the modern world is a data-driven world. We are surrounded by data, numerical and otherwise, which must be analyzed and pressed to convert to information, which informs, instructs, answers, or otherwise aids understanding and decision making. The quantity of such data is huge and growing, the number of sources is effectively unlimited and the range of areas covered is vast: industrial, commercial, financial, and scientific activities are all generating such data. In agriculture this move designates our research roadpath to new dimensions of knowledge exploitation.

The consumer demand for quality and safety food with environmental sustainability and the market requirements for low cost and price can only be met in a knowledge based society. So IoT is the enabling technology to gather info from the field and AI techniques are the means to convert to knowledge and compared to Scientific Background knowledge leads to best decisions to take.

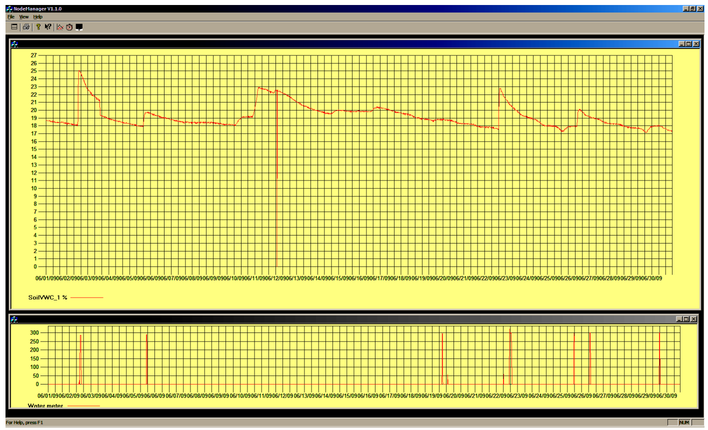

Fig. 6: Graphical of Treatment A VWC (graphic in top), Irrigation Events (lower graph). PRI June 2009

At field level we will remain with electrohydraulic systems that need or supply energy and materials (machine works, fertilizers, chemicals, etc.) and the IoT will connect the field to the knowledge world for making best decisions, which will be based on world's first experts and knowledge centers. SOA and Ambient Intelligence will open the road to Intelligent Agriculture which we expect to:

- Improve Performance And Cost Of Supply Chain Management
- Improve Resource Efficiency
- Enhance FOOD SAFETY, SUFICIENCY And QUALITY
- HUMAN SAFETY
- Climate Change Adaptation And Mitigation
- Improve Production Economics (Farmers' Income And NGP).

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