Monitoring Dashboard for Cloud Sustainable Greenhouses

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Abstract
The growing evidence of major environmental changes promotes sensitivity to the causes that give rise to them. The companies, namely the ones focused on agriculture production in Greenhouses, are concerned with their production efficiency and business success and the persons are concerned with their possible contribution on those (abnormal) environmental events and, indirectly, with their effects on their own health.

Greenhouse production involves several and distinct resources or services, from time and persons to multiple type of equipment. If most of the production knowledge lies on human experience, the capacity to decide quickly against real situations comes from the availability of real and useful information, timely.

Accepting Chang [1] perspective that Cloud Computing “provides scalable and inexpensive on-demand computing infrastructures with good QoS… as well as new business opportunities for service-oriented models”, it outlooks that Greenhouse Production under a cloud architecture supporting information systems control, has the potential to be sustainable.

Therefore, the aim of this paper is to:

a) demonstrate that existent technological initiatives are not sufficient for efficient control of sustainable Greenhouses;

b) propose an ICT platform based on open source technology composed by: i) a servo unit, using embedded technology, that allow the integration of several sources of data (raw data, sensors, cameras, drones, etc.) existents in the Greenhouses; ii) a dashboard to monitor and control remotely required Greenhouse production variables and equipment; iii) an API mainly supported by Restful services, for future integration of new devices or systems and iv) a Decision Support System to help the Greenhouse management, remotely.

c) propose a cloud architecture to support the integrated information system, to store and help processing the huge amount of data, efficiently, towards the sustainability of the Greenhouse;

d) evidence that the use of communication channels is essential for effective management and represent the necessary add-on to ICT;

1. Introduction
Nowadays, it has become known the importance of undertaking actions that reduce the environmental impact within all sort of processes, both industrial, business, or in our daily lives.

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An already wide range of literature reviews exist about the various aspects and facets of this concern, for instance, the green supply chain management [2], green building [3], green manufacturing [4], green product life-cycle and services [5]. And naturally both green IT and green IS are today central issues [6], [7].

In this context, generic greenhouses sustainability are the subject of several research projects of monitoring and control, as represented by [8] [9] examples. Sustainability here means the capacity to control the internal environment, essentially.

The Greenhouse production needs to start changing its business paradigm. It is clear that this activity involves several distinct resources (and services), from time and persons, multiple infrastructures and type of equipment, and, besides the expected production results, there are continuously relevant data that is generated and needs to be processed. In the emerging Cloud Manufacturing [10] context, accepted as a tentative to shift from production-oriented to service-oriented manufacturing, IT services are seen as instances of (traditional) resources, since any (manufacturing) activity needs to look to the global market.

But if most of the production knowledge lies on human experience, the capacity to decide quickly against real situations comes from the availability of real and useful information timely (extracted from the data generated).

Some of this information can come from the User Experience and capacity to analyse the current production results, but some other might not. The capacity to mitigate (or integrate) all this enormous, but diffuse, information that all resources produce continuously, is a hard and delicate task. The use of auxiliary equipment (and solutions) efficiently integrated is an add-on that producers need to have, in order to ensure their business sustainability [11].

Accepting the almost omnipresence of Information and Communication Technologies (ICT) in our quotidian, the rising of Cloud Computing (CC) lead us to believe that, technologically, it is possible to have virtually unlimited resource capacity for computing and storage [12] and the ubiquity support for traditionally centralized applications can be a fact [13]. Typically, such ubiquity can only be supported if multiple resources inter-operate efficiently and can dynamicaly be reconfigured. Nevertheless, this capacity is one of the main challenges of cloud computing [14]. Indeed, new technologies provide new experiences (and persons love that), and consequently new ideas arrive. However, new resources (not only technological) are required too.

This spiral of events represents evolutionary steps to the raising of a technocentric society, as an analogy to the egocentric stage in Piaget's model [15]. But technologies will not be sufficient if human behaviour does not change too. The "intelligence was not the product of any simple recipe or algorithm for thinking, but rather resulted from the combined activity of great societies of more specialized cognitive processes" [16].

The cloud paradigm enables the efficient retrieval of information from multiple data to achieve an efficient monitoring and control. New devices (mobile, mainly) and emergent communicational technologies demand richer information systems. Generally the use of dashboards represents an appropriate tool on decision making, but expanding it with efficiently integrated communicational services that allow human-to-human co-decision, represents a relevant added value.

Because the greenhouse production is (increasingly) commercialized in more global markets, the existence of efficient mechanisms to deal with unknown customers and service providers, is a critical requirement. Thus, its sustainability should not be seen only based on its internal capacity to produce but in the capacity to manage well all the participants in the system.

In traditional ICT transactional architectures, the human behaves as a mere user from outside the system, making impossible to have an effective human interaction. Thus, the real user (human)
requirements cannot be well supported indeed, because they are not easily tangible and technically specifiable. The user will need to continue to adapt to the system and follow the system wizards. He cannot have his own reasoning and interact humanly with the system [17].

Under the cloud SaaS (Software as a Service) model, the application’s Presentation Layers are now structured in a set of widgets (cloud-based full-fledged applications or cloudlets [18]) or specialized Apps, to support a service that can easily be “composed” (integrated) in a dashboard “expected to improve decision making by amplifying cognition and capitalizing on human perceptual capabilities” [19]. Despite of this, the components are not effectively integrated, but merely functionally organized, indeed. Furthermore, besides the restricted inter-interoperability, the lack of effective and really integrated communicational instruments, essential to enable the user participation (embedding his experience) on decision processes, represents another important weakness.

The state of the art confirms the existence of many attempts to project and develop cloud based solutions. The Greenhouse Drone from iNano Institut; the Akisai Food and Agriculture Cloud, from Fujitsu; the IOS HomeKit that explores a complex network of sensors offered as greenhouse automation services, from Apple; the Agriculture Greenhouse Automation with remote sensors under XBee modules, from University of São Paulo, etc., are relevant examples of such initiatives. Also relevant is the fact that all those proposals focus on technological solutions and in the Greenhouse Environment Control, essentially. To the best of our knowledge, at the time of this writing, none of the projects is already implemented.

2. Towards Sustainable Greenhouses

Like multiple economic activities, traditional manufacturing has been hardly “shaken” to efficiently integrate ICT in their processes. Nevertheless, efforts to modernize legacy applications or systems and to capitalize traditional knowledge, still continue to slow down an efficient ICT adoption and consequent business model changes, an essential requirement to re-align with new market requirements. In this process the human has been a passive actor and the knowledge does not represent the real human capital. Indeed, following working processes and responding to system’s events can be efficient enough (can be measured), but does not allow the co-creation of knowledge and thus unable to be effective.

2.1. More than an innovative business model

Nowadays social-economic trends such as consumption growing, globalization, innovation and sustainability policies, determine new orientations. The agriculture production in greenhouses has been looking for low cost processes and scalable production capacity [20]. Apart from the required (internal) environment controlled resources (humidity, watering, sanitation, etc.), some other resources involved in this type of production (human resources, equipments, etc.), even existent in a global market, must be discovered, selected and managed, and the capacity to get the “best” ones will be determinant, but it is not enough to achieve the expected efficiency and sustainability [21]. A possible scenario can be the choice between hiring an expensive full time Agriculturist Hydroponics instead of having their services whenever necessary (surely less expensive. The easier the engineer can efficiently (remotely if needed) support his responsibility, for one or many greenhouses, the more effective and cheaper will be its services.

Agility and quickness are critical in nowadays competitiveness requirements. The globalization, innovation and ICT are transforming many sectors to anywhere, anytime platforms. Traditional stakeholders (technicians, suppliers, customers, others) can be “transformed” into services and following Putnik, these are the essential requirements to react to global market changes and the
main problem arises from the people themselves, whose mind-sets need be changed. So the challenge is not only the ICT adoption but more the way one does it [22].

2.2. New shift on Agriculture in Greenhouses paradigm

As happen with several other existing business areas, a greenhouse business has essentially providers, customers and collaborators involved. But the real perspective arises from the assumption that the set of “stakeholders” involved in a production in greenhouse is increasingly greater each day, independently of the specific, or not, kind of cultivation explored. This assumption comes from the concept of service. There are several services involved, indeed, and services: a) are not necessarily supported by humans; b) could not be supported by machines; c) could not be part of the greenhouse company and d) could be internal or external.

The greenhouses traditionally need to have: a) its internal environment completely controlled and managed; b) the supply chain managed; c) the knowledge of customer’s requirements and d) the business trends perception. Furthermore, the emerging business models implies yet: a) global perception of concurrent “threats”; b) global perception of interesting and available “services”; c) perception of the quality of the “services” and d) the ability and capacity to dynamically reconfigure the provision of “services”.

But emerging (changing) agriculture in the greenhouse paradigm will need to be definitively sustainable and thus requires the possibility:

i. to follow and assimilate all resource efficiency recommendations (green energy, green IT, etc.)

ii. to manage efficiently all the (contracted) services, having monitoring dashboards that allows:
   i) to analyse the quality of services provided; ii) to know the status of any internal environmental indicator controlled by external services; iii) to interact immediately and personally with the “owner” of a particular service; iv) to broker for alternative services; and v) to interact or integrate with (other) independent (related) institutions (security, firemen, etc.)

iii. to easily assimilate external (and concurrent) collaboration, where interested collaborators (suppliers, engineers, technicians, etc.) need: a) “to convince” the company to accept their services; b) have appropriate skills for the required specialized tasks; c) have availability and capacity to remotely support the required tasks; d) have the capacity to managed several tasks for several interested customers (greenhouses); and e) have appropriate (technological) tools to support their job.

The sustainability is not based only on the resource’s efficiency but also on the capacity to efficiently manage the networks of collaborators. Following the behaviour of social networks, the collaborators must be able to join the company (offer their services) easily and the company must know that they exist, which are the best collaborators and how to interact with them.

2.3. Cloud, Ubiquity and Pragmatics: emerging challenges

Nowadays dynamic and global business models brought the need to quick react to market changes, and the high availability and capacity to effectively support the changed requirements, becomes the main sustainability criterion. To handle that, companies need to have appropriate information systems that allow permanent real and effective perspectives of the market of resources, with efficient tools to broker and select them. The possibility to have the needed resource, in the needed time and where it is needed, represents the advantage of, and requirements from, Cloud and Ubiquitous Information Systems [21].
Furthermore, the huge amount of (real-time) data coming from (environmental) internal resources and services, together with the information coming from the network of external collaborators (mainly services), requires considerable storage and processing capacity. Thus, the need to have enough (in quantity and quality) resources and an efficient network of suppliers, in a dynamic and continuous reconfigurable environment, brings cloud based infrastructures as an important add-on to support these new information and processing systems.

To align the system to human, the system architecture needs to support human-to-human real and synchronous collaboration that allows the co-exploration (co-creation) of the system with other agents (humans). Thus, the architecture needs to be communicational based, having direct human participation and collaboration in any particular phase of the production process. Assuming this, Pragmatics [21] and Collaboration engines together with effective brokering mechanisms need to be implemented. The evidence of this comes from today’s social networks success and their use for our own interest in a completely autonomous way. The larger the communicational capability of the architecture is, the greater is the effectiveness of the system.

3. Cloud and Effective Dashboards for Sustainable Greenhouses

Cloud Computing is much more than unlimited IT capacity. It is an opportunity to achieve, indeed, new business models. The success of human capital promotion with social media, and the new communicational (smart) devices capacities, brings web (wired or not) to high levels of intelligence support, supporting value creation and (self) efficient business models to use it [23].

3.1. Cloud Communicational Architecture

To overcome the evident and known technological interoperability handicaps, a semiotic framework [22] is required, based on an architecture that sustains two main characteristics: a) ubiquity, that cloud should grant to the registered resources (and services), since it focus on the agility and quickness competitiveness requirements, and b) communicational, where innovative and efficiently integrated communication tools will support the semiotic features (pragmatics).

So, such framework will be supported by a Cloud based Communicational Architecture (Figure 1) built on open-source technology, that has integrated: a) RIA pattern based dashboards [24], with integrated monitoring services and sufficient interaction to allow human (user) agility and
competence, b) multimodal capacity, for multiple client device classes support, c) communicational services to allow pragmatics (considered as its innovative part), where human-to-human real interaction is completely supported, and d) scalable storage and processing capacity to assure the real-time required data processing and flow.

The semiotic component (Figure 1 (a)) of this architecture will be supported by a Pragmatics Rendered [17] that works as a communication enabler, and consists of a set of integrated collaboration technology that makes the bridge between the user/devices and the “system”. A federated or community cloud (Market of Resources) will be created using a particular cloud RESTful API that will support (cloud) services composition and governance (pragmatics services behave as SaaS in the cloud). The communication services will be supported by existing P2P technology and rich and innovative cloud communicational services must be explored (SignalR, WebRTC, LoKast, etc.). A specific and advanced brokering mechanism will support the selection of resources (or services) and the dynamic reconfiguration (the Market of Resources will behave as a PaaS), using big data processing technologies.

3.2. Greenhouse Effective Monitoring Dashboard

The global ICT platform proposed (Figure 2) will be composed by: i) a servo unit, an infrastructure middleware type with embedded technology, that allows the (continuous) integration of several sources of data (raw data) coming from existing equipment (sensors, cameras, drones, etc.) in the greenhouse (Figure 2 a)); ii) an opened SaaS RESTful API that will support the integration of new equipment or collaborators (devices or services) (Figure 2 b)); iii) a rich and effective dashboard to remotely monitor and control the required greenhouse production variables (internal and external) and inherent equipment (Figure 2 c)) and collaborators network, allowing co-decision processes, and iv) an integrated Decision Support System to help on global greenhouse management.

Figure 2 - Architecture of the Global Platform

Functionally, the dashboard (Figure 3) must have integrated several outputs resulting from several sources of data and must be prepared to be used by distinct user profiles. Considering the sources of data, there will be data coming from the greenhouse (internal) “equipment” (humidity, temperature, etc.), as well as data coming from external collaborators, such as the QoS provided by a particular engineer, his availability, their reports, their decisions, recommendations, scheduled tasks, etc.

Considering the user profiles, the application should be used by full members (Figure 2 d)) of the greenhouse as well as by external collaborators (Figure 2 e)). Naturally each profile has a particular
set of features but the most relevant comes from the existence of an integrated set of communicational channels (Figure 3 a)) that allow direct and immediate (synchronous) collaboration, an essential requirement for effective co-decisions.

Figure 3 - Effective Dashboard

The existence of an Integration API allows the possibility for anyone to register into the “network” of resources (cloud services) and thus be available to the resource brokering mechanism. The greenhouse manager can, carefully, select the “best” provider for the service that is needed.

A Decision Support System will help full members and collaborators to manage all complex situations. Wizards should take care and orient on solving alert situations or reconfiguration needs, for instance.

In the following developments, this platform will be prepared to be adapted to different contexts or scenarios. Such platform fits, among many others, in critical scenarios for humans, with delicate or dangerous situations, such as examining mines, wells, underground viaducts, hostile environments, etc. Its capacity to integrate new equipments (robots and drones are possibilities, indeed); its capacity to process huge amount of data; the existence of effective communication tools and the existence of an open SaaS API, makes it able to be continuously explored.

References and Bibliography


