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Monitoring Dashboard for Cloud Sustainable Greenhouses

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Abstract

Today it has become clear the importance of undertaking actions to reduce the environmental impact within all sort of processes, both industrial, business, or in our daily lives. An already wide range of literature reviews exist about the various aspects and facets of this concern, for instance, the green supply chain management (Srivastava, 2007), green building (Eichholtz, Kok & Quigley, 2013), green manufacturing (Deif, 2011), green product life-cycle and services (Funk *et al.*, 2014). And naturally green IT, green IS are today central issues (Loos *et al.*, 2011; Meacham *et al.*, 2013).

In this context, greenhouses sustainability are the subject of several research projects of monitoring and control, as can be found in (Du, Ma & Feng, 2013; Li *et al.*, 2013; Xufeng *et al.*, 2013; Yin *et al.*, 2014; Zhang *et al.*, 2013).

Thus, considering that the emergent environmental problems represent a critical and relevant part of the global and social problems of nowadays, the Information and Communication Technologies (ICT) continue to be seen as the basic lever for the continuous business models transformations and consequent creation of possible solutions to efficiently manage their identified causes. Indeed, new technologies provide new experience, and consequently new ideas. 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 (Papert, 1987). 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"*(Singh, 2003).

Focusing on ICT, we face the possibility to have virtually unlimited resource capacity for computing and storage, with on demand scalability to accommodate both users and application requirements (Charlton, 2008). It is the Cloud Computing (CC) era. Current trends in CC bring ubiquity to applications that were typically centralized and with a single point of access. Ferreira et al. (2012) focus on the ubiquity and continuous features of any cloud solution, as a relevant technological architecture to support new business models. Typically, such ubiquity is achieved through multiple resources which must inter-operate efficiently, this in turn is one of the main challenges of cloud computing (Becker, 2012).

Nevertheless, the nowadays CC success and the emergent Information Society Technologies (IST) (Mahieu & Arnold, 2009) force business activities to follow cloud-adoption process. Accepting Chang (2010) perspective that CC "*provides scalable and inexpensive on-demand computing infrastructures with good quality of service (QoS) levels...also provides added value for organisations; saving costs in operations, resources and staff – as well as new business opportunities for service-oriented models*", it outlooks that Greenhouses Production under a cloud architecture with support for information systems control, has legitimized potential to be sustainable.

Greenhouse production has traditionally been located near population centers. However, the increasing lack of ideal soils where: a) the quality, light, wind humidity, temperatures, are controlled and appropriate; b) the easy access to markets is ensured; and c) sufficient room for actual production or future expansion and parking, is a relevant criterium to construct the greenhouse in distant and multiple places. Thus, the possibility to spread Greenhouses is evident and the need to control them remotely is a requirement. In another perspective, each Greenhouse production involves several and distinct resources, from time and persons to multiple types of equipment, that produce continuously relevant data. If most of the production knowledge lies on human experience, this capacity to decide quickly against real situations comes from the availability of real and useful information (local data), timely. Some of this information can come from a visual analysis of the current production, but other might not. The capacity to mitigate (or integrate) all this enormous existent, but diffuse, information that all resources produce continuously, is a hard and delicate task. The use of auxiliary equipment efficiently integrated is an add-on that producers need to have. We are dealing with a typical business scenario where different entities must be efficiently coordinated and managed, to ensure its sustainability (Garetti & Taisch, 2012).

Many of these equipments are increasingly being supported by electronic devices like sensors. Although temperature, humidity of the air or soil, light intensity, etc., are already interpreted by such type of equipment, their integration is not already easily supported and their interpretation and correlation even less. And the more equipment is involved, the greater the amount of data that must be processed. The emergence of increasingly complex technologies inherent to more complex and powerful equipment and the absence of standards for their interoperability, depending on their application, the design and development of solutions that need to use them, require various kinds of both technical and nontechnical expertise.

Since cloud enables the use and interoperability between multiple resources, we defend its use to enable the monitoring of the environment through a wide range of sensors and other eletronic devices, that produce huge amount of data that has to be stored and processed to extract knowledge. 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 event more rich information systems, making services to move to cloud based app models. The use of dashboards to show all existent information represents an appropriate tool to help the manager in decision making. Expanding these dashboards with efficiently integrated communicational cloud based services that allow human-to-human co-decision, represents a relevant added value.

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 allows the integration of several sources of data (raw data, sensors, cameras, drones, etc.) present in 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, representing the necessary *add-on* to ICT;

This paper proposes a monitoring and controlling dashboard for Greenhouses, supported by a cloud and ubiquitous architecture, towards an efficient, effective, sustainable and passive eco-environment, where human-to-human relations allows the essential co-creation and co-decision in this business area.

Keywords: Greenhouse; Sustainaility; Cloud Computing; Interoperability;User Experience; Effectiveness; Co-Decision; Dashboard.

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