# Concepts for Agriculture and Tourism Cyber-Physical Ecosystems

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*Abstract*— **Nowadays is quite common the usage of robotics and automation combined with smart electronics and embedded systems, in manufacturing or enterprise processes. Such elements work together to augment systems intelligence in decision making for actuation representing the so-called Cyber Physical Systems concept. Due to the amount of data generated by enterprise processes tools, which go either uncollected or unprocessed, as well as, the need for greater coordination of those processes for reducing inefficiency and downtime among other factors, Cyber-Physical Systems have been introduced to support such activities. Thus, and apart from the level of automation or the industrial sector, their dependence in these types of systems have been increased. The objective of this paper is to describe some concepts; approaches and analysis to facilitate an efficient and structured implementation and use of technologies related to Cyber-Physical Systems specifically in agriculture and tourism industries. Authors introduce the concept and the idea that enterprises systems have four states of working, which Cyber Physical Systems act as the catalyst for the transitions between the solid, the liquid, the gas and the plasma states, establishing by this way a parallelism to the states of matter.**

## I. Introduction

The agriculture and tourism sectors are highly important for the European Union's social and economic welfare. Agriculture represents around 10% of Europe's GDP, while tourism is the third largest socio-economic activity in the EU. Agriculture employs around 25 million people, while the tourism industry provides work for another 10 million. However, European Agriculture is faced with three main challenges, namely, changes in climate which affect agricultural production rates, as well as, increasing energy costs (electricity and fuel) and reduced water sources, due to increased demand for this scarce resource. The EU's tourism industry faces similar challenges. Although Europe is a culturally rich and interesting tourist destination, the emergence of new destinations in other regions, has decreased some of the demand for European tourism spots. Additionally, the impact of rising transportation costs, due to higher fuel prices, can also deter attracting tourists from outside Europe. There is therefore a need for solutions which can assist both agriculture and tourism enterprises to become more efficient and cost effective in their operations.

This paper intends to contribute towards helping the EU's agricultural and tourism enterprises in remaining competitive, providing a solution and tools which will help them in better managing their resources and to more effectively adapt themselves to changes in their operating environment. The paper provides a new paradigm, implementing a new concept based on state of matter (solid, liquid, gas and plasma), developing a novel platform and toolbox, which will assist agricultural and tourism enterprises in effectively manage their business and environmental context. With appropriate smart sensorial-based tools, as well as, pro-active event processing, enterprises can react and adapt themselves in real-time to events which can influence their business, such as weather, market or social phenomena. It is propose the necessary components, from embedded systems and sensing devices, to a framework and software platform, which will enable companies to deploy smart Cyber-Physical Systems (CPS) solutions in their surrounding environment. The solution will be demonstrated in agricultural and in a ski resort settings, performing proper real-time sensorial data acquisition, knowledge analytics and management, and taking pro-active actions which will assist them in reducing costs, in being more efficient and in providing better service to their customers.

In this paper, the authors intend to draw attention to the use of CPS technology in agriculture and tourism scenarios with the goal of showing the potential benefits and respective cost savings provided by the implementation of these tools and demonstrate the importance of these technologies nowadays in industry. In section II the author`s proposed, a study of CPS, where is described it`s definition tools, objectives and applications. In section III, it is presented various enterprises' types (e.g. sensing enterprise) and its four states (the solid, liquid, plasma and gaseous states). Section IV identifies the positioning in the agriculture and tourism industry challenges and respective scenarios, one for each industry. In section V it is presented the modular architecture to enable the scenarios' application development. Conclusions and prospective future work are described in section VI.

## II. Cyber-Physical Systems

CPS or "smart" systems can be defined as co-engineered interaction networks of physical and computational components [1]. These systems are at the heart of our critical infrastructure and form the basis of our future smart services. These promise increased efficiency and interaction between computer networks and the physical world enabling advances that improve the quality of life, including advances such as in personalized health care, emergency response, traffic flow management, and the electric power generation and delivery [2]. Other tools or technologies related to CPS include: Internet of Things (IoT); Industrial Internet; Smart Cities; Smart Grid and "Smart" Anything (e.g., Cars, Buildings, Homes, Manufacturing, Hospitals, Appliances) [1]. Key stakeholders in CPS have identified the need to develop a consensus definition, reference architecture, and a common lexicon and taxonomy. These will facilitate interoperability between elements and systems, and promote communication across the breadth of CPS stakeholders. As these concepts are developed, it is critical to ensure that timing, dependability, and security are considered as first order design principles [2].

With the emergence of high speed broadband and the IoT, the embedded world is meeting the Internet world and the physical world meets the cyber world. In the future world of CPS, a huge number of devices connected to the physical world will be able to exchange data with each another, access web services, and interact with people [3]. One example of CPS is an intelligent manufacturing line, where the machine can perform many work processes by communicating with the components [4].

In conclusion, CPS are physical and engineered systems whose operations are monitored, coordinated, controlled and integrated by a computing and communication core. Just as the Internet transformed how humans interact with one another, CPS will transform how we interact with the physical world around us [5]. Therefore, using sensors, the embedded systems monitor and collect data from physical processes, like steering of a vehicle; energy consumption or human health functions are networked systems that make the data globally available. CPS make it possible for software applications to directly interact with events in the physical world, for example to measure peaks in energy consumption [4].

## III. Enterprise Systems and their Four States

This paper foresees the development of a modular CPS architecture, as presented in section V, which could facilitate the establishment of collaborations between enterprises through the sharing of resources and assets among them with the objective of increasing autonomous systems able of satisfying multiple critical constraints including safety, security, power efficiency, high performance, size and cost. The main idea is to use CPS features to act as a catalyst of business collaborations generation and decision making, which underpins the generation of dynamic enterprises processes that are able to smoothly change their state of working. This means that such dynamic enterprises continually transform the multitude of changes occurring around it into coordinated strategic actions by its people or systems to further the development of its products and services [6].

Sensing Enterprise was introduced in 2011 by the Future Internet Enterprise Systems (FiNES) initiative to describe a business environment in which all assets are endowed with sensing capabilities and connected to networks to ‘treat’ information, generate new knowledge, help quick and effective decision making and, in so doing, make the Future Enterprise [7]. This concept intends to go beyond of such enterprise handling sensing features, accomplishing on its top a new generation of modular architectures elements accomplished by embedded systems characteristics and acting as software agents, which will enable a high degree of autonomy ensuring adaptability, scalability, complexity management, security and safety, and providing trust to humans in the loop. These new generation of novel architectures are represented as ‘cyber assets’, which as defined by Tow [8] in include in its component, the key information and knowledge resources, including the data, policies, reports, IP, algorithms and applications, programs and operational procedures that a modern society in the 21st century relies on to operate and manage its business.

The proposed main concept resides in the idea that enterprises have four states of working: the solid, the liquid, the gas and the plasma states, establishing a parallelism to the state of matter (Figure 1. ). In the state of matter, the enthalpy represents the thermodynamic potential of the matter to change its state to another. Thus, the change depends mainly to the heat added or released in the matter; the other characteristics are the volume and the pressure. On the enterprises case, such potential is characterized mainly by the capability of absorbing or releasing knowledge between the states by the system; the other characteristics that have influence in such process are the interoperability and the automation abilities. As stated before are the CPS features the main catalysts of such dynamism, which would potentiate the changing of the state.

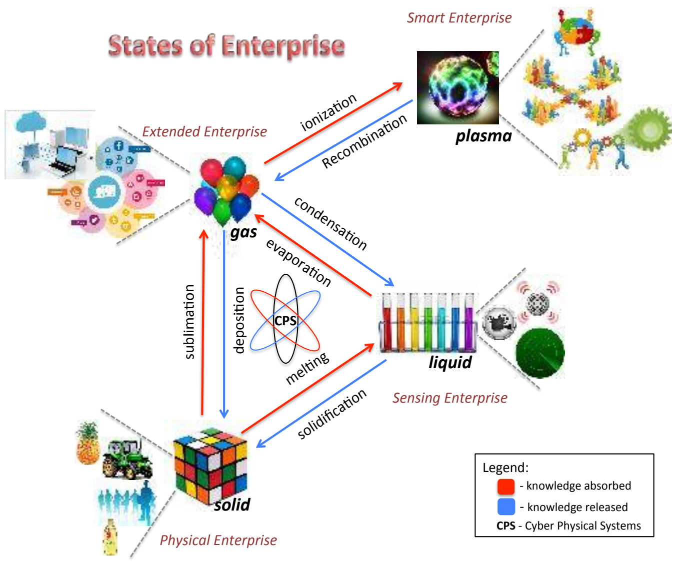


Figure 1. States of Enterprise

### A. *Solid State or Physical Enterprise*

An enterprise is a socio-economic unit, integrated by human, material and technical elements, which aims the goal to obtain utilities through their participation in the market of goods and services. In this sense, makes use of production factors (labour, land and capital). A physical enterprise is characterized by do not use technological systems to establish business networks and to handle knowledge about its domain. In additional, it is similar to a “solid”, meaning that structural rigidity and resistance to changes of shape or volume characterize it [9]. In the proposed concept case, enterprise’s processes will interact with the physical or solid assets of an enterprise managing them with indications and receiving (human) feedback.

### B. *Liquid State or Sensing Enterprise*

The Sensing Enterprise state relies upon the collection and processing of several types of data, from a wide variety of sources, including sensor networks. If the data collected is to be useful in the support and decentralization of its decision-making capabilities, the data gathered must be transformed into actionable information and knowledge. Knowledge management principles can and should be applied as they can assist in the fulfilment of the Sensing Enterprise vision. It states that enterprises with sensing capabilities will be able to anticipate future decisions by the understanding of the information handled, which enables specific context situations awareness. Thus, the Sensing-Enterprise interconnects physical (e.g. sensors, actuators), digital (e.g. sensors & web data, explicit knowledge) and virtual (e.g. simulation & prediction information) worlds in the same way as a semi-permeable membrane permits the flow of liquid particles through itself. This represents the Liquid State, like in the states of matter, the enterprise has a definite volume but no fixed shape, it has the capability of handling the knowledge associated to a predetermined set of resources, physical or not, that are interconnected to the system. It can be manageable and adapted to all kind of circumstances or objectives as liquid do when in contact to other shapes it simply takes its shape form.

### C. *Gas State or Networked Enterprise*

The state of matter distinguished from the solid and liquid states by: relatively low density and viscosity; relatively great expansion and contraction with changes in pressure and temperature; the ability to diffuse readily; and the spontaneous tendency to become distributed uniformly throughout any container [10]. A networked enterprise is any undertaking that involves two or more interacting parties. A virtual enterprise is a temporary network of autonomous firms dynamically connecting themselves stimulated and driven by a business opportunity arising on market. Every member makes available some proprietary sub processes and part of their own knowledge.

### D. *Plasma State or Smart Enterprise*

Plasma is one of the four fundamental states of matter (the others being solid, liquid, and gas). It comprises the major component of the Sun. Heating a gas may ionize its molecules or atoms (reducing or increasing the number of electrons in them), thus turning it into a plasma, which contains charged particles: positive ions and negative electrons or ions [11]. Smart Enterprise is about transforming our organizations to take advantage of the capabilities of smarter ecosystems, so enterprises can make more informed decisions, build deeper relationships and work with more agile and efficient business processes. The new enterprise organizations, such as virtual enterprise and smart enterprise, require the usage of collaborative automation approaches, addressing the flexibility and dynamic re-configurability [12].

### E. *States of Enterprise and CPS*

This concept intends to address the processes required to change of state of working by an enterprise. It intends to answer the necessary characteristics which enable enterprises to have systems able to handle knowledge and collaborations underpinning the idea of a dynamism, where enterprises can change their state concerning specific situations as matter do in nature. It depends on the knowledge shared, automation, interoperability and intelligence. CPS is the fuel to introduce new knowledge to the system. CPS is able to acquire knowledge in some situations that will enable enterprise systems to actuate and originate the creation of specific approaches or processes that in relation to the presented concept will push the enterprise to another state of working.

## IV. Current Agriculture and Tourism Industry Challenges and Scenarios

### A. *Positioning in the Agriculture Industry*

One of the most important challenges of our century is to ensure the proper framework that will allow feeding the entire population of the planet, in the context of severe climate, different soil quality and population growth. The quality and quantity of agricultural products as primary elements of the food requirements for the population are representing since long ago a major preoccupation of both agriculture specialists and, in particular, of governments. The increase in the production and, implicitly, of the productivity in agriculture are subject to severe constraints with respect to inherently limited resources, less qualified workforce and agricultural terrains that are decreasing in size and productivity. According to “Food and Agriculture Organization of the United Nations” [13] predictions show that in 2050 the agricultural production will double as a result of the increasing level of automation, but also of the scientific and technological progresses with respect to the soil improvement and development of new and more efficient species of plants and animals.

One of the major resources for the increase of the productivity is potable water, which is now, in a continuous decrease, as it is estimated that 2/3 of the Earth population suffers, more or less, from its insufficiency. Consequently, the management of irrigation systems needs to be re-designed and soil humidity control and monitoring systems shall be improved in accordance with the evolution of integrated, embedded and CPS, sensing networks and of interconnected actuators. Mechanical and automated systems, successfully implemented in agriculture will lead to increased productivity, a decrease of the human resources involved and, globally to a more efficient exploitation of the soil. Also, the progresses in ICT will lead to a paradigm change, where the concept of CPS could find a rich domain of implementation.

#### *Smart Plantation Scenario*

In the current globalised context, enterprises and especially manufacturing enterprises survival depends on their ability to produce goods in a competitive way and adapt their organization, processes and products in a quick and suitable way to the market and social changes.

The agro food supply chain can be considered as a Collaborative Networked Organization (CNO) with a federated governance model, with the responsibilities shared among players and stages all along the supply, from farm to the point of sale, reaching the consumer. To have the ability to efficiently produce highly customized and unique products, the agro food supply chain need to work as a single ecosystem where devices, machines, information systems, external data are orchestrated and correlated each other so as to make the knowledge behind the manufacturing line tacit and available for making decisions at tactical and operational level.

The integration of CPS in agriculture can be defined in three different stages. The first implementation stage is to ensure the parameterisation of the customer request in terms of different groups: filed, harvest, elaboration, quality measures, and sensory properties. A wireless sensory network (WSN) can monitor permanently the different parameters along the manufacturing process from the field to the manufacturing. Collecting data by such WSNs, their correlation with the parameters of field control and monitoring systems as well as with external factors (customer outputs, market evolution) can impact agricultural productivity and support strategic decisions with respect to the development of plantations. Thus, at field level can be found: weather stations to monitor the most relevant environmental parameters, such as temperature, relative humidity, solar radiation, wind speed and rainfall; soil sensors to estimate moisture, temperature and electrical conductivity (indicator of nutrients), plant sensors to measure size and thickness of stems, leaf wetness and fruits sizes; and specific visual sensors to obtain remote images of some quality parameters (aspect, diseases, damages).

A second stage consists of the acquisition of production data from the information systems (e.g. sensors) spread all over the production places. Information about traceability, quality control, stock, production planning can be acquired and compiled so as to serve as a knowledge base of the intelligent control at the physical level of the agricultural production and manufacturing, able to ensure a constant quality of products. In order to ensure the adaptability of the production to the external conditions – weather, market, food and feed alerts, regulations – it appears as a necessity the existence of a web intelligence network features (crawling, scraping), which represents an example of virtual sensors able to be used. Web services architectures, semantics and interoperability technologies to allow the orchestration of data coming from heterogeneous legacy systems sources are required to then integrate CPS at the next stage.

The final stage implies a CPS approach and results in an emergent pro-active behaviour of the agro food supply as a system, putting the previous stages all together. By correlating the real-time monitoring system and the existent knowledge embedded with the production planning and status, integrated with an intelligent control system and with estimation of the external world evolution (with respect to the agro food supply chain), the CPS system will be able to interpret different information received from channels as sensors, humans, devices, systems, even social media channels or web public sources, in order to identify and even predict relevant contextual changes at tactical and operational level, to which the company should adjust to align with the customer request.

As a scenario example using the presented enterprises states concept, if a possible disease in a plantation field is detected by a specific sensor it could require further confirmation from other sensors nearby, which may belong to another neighbour enterprise or field. This process represents the move from a sensing enterprise situation (liquid state) to another state (gas state), where through specific network of knowledge and services the system can check other environment variables that have a direct influence in plants diseases propagation as the weather. This enables more efficient actuation as in the request to a specific treatment. In such mentioned actuation process the system supplies additional information or knowledge to the “physical” part of the enterprise in a kind of “deposition” process (see Figure 1). Through such information, the “physical” part of the enterprise (e.g. farm employees) could react accordingly and conduct the appropriate treatment.

### *B. Positioning in the Tourism Challenges*

As the third largest socio-economic activity in the EU, tourism is important for growth and employment. Despite the depth of the economic crisis, the tourism industry in the EU has proved resilient with numbers of tourist trips remaining high. However, long-term trends suggest Europe is losing position in the global marketplace, with new destinations gaining ever-growing market share. The Lisbon Treaty provides for faster and easier decision-making on EU measures in the field of tourism, allowing decisions to be taken through the ordinary legislative procedure, even though it has not substantially increased the scope of EU powers in the area. Drawing on the new Treaty provisions, the European Commission has prepared a new policy framework, whose main objective is to make European tourism more competitive, modern, sustainable and responsible. The strategy, entitled “Europe, the world’s No 1 destination – a new political framework for tourism in Europe”, was welcomed by the European Parliament, which nonetheless underlined the need to better coordinate tourism-related issues within the Commission and to clearly signpost financial support for tourism-related projects. The Parliament has also recently underscored the importance of tourism-related activities in different policy fields such as in rural, maritime and coastal areas [14].

#### *Smart Mountain Resort Scenario*

Winter resort is a complex organization which involves the coordinated deployment of the multiple and diverse services, such as: customer services, hospitality services, lift management, snow making, slope grooming, slope inspection, technical maintenance and repair, procurement, mountain rescue services, forest services, road maintenance, medical, parking, ski equipment rental, weather monitoring, ski school and fire rescue. At this moment, Bergfex.com lists a total of 1668 winter ski resorts in 12 European countries. Such ski resorts can be also considered as a CNO [15] with a federated governance model, with the responsibilities shared among winter resort management, hotel property owners, mountain rescue, regional roads' maintenance company, municipality and even state-level organizations (e.g. national parks), and others. Smooth operations of the winter resort management and their coordination with other stakeholders have significant impact on the development of the local region, in terms of revenue, employment and sustainable development.

However, due to complexity of the federated governance model, the services coordination is often far below the optimum level, leading to the issues, such as lower customer satisfaction, inefficient energy consumption, increased total cost of operation and sometimes even higher probability of the critical events, such as injuries, avalanches and forest fires. The problems above are multiplied by the fact that, due to a climate change, the resorts are also forced to continuously work on adapting the services and even on natural hazards management [16]. Figure 2. presents the illustration of the governance (solid lines) and dependences (dashed lines) of selected services in Winter Resort Management. It also demonstrates the inefficiencies of the current operation practices, mostly related to the coordination of the different services.

For example, slope inspection is the service provided by the specific department of the winter resort enterprise that collect and share information about the current snow and slope conditions, but also about the slope congestion. In case of the bad conditions, a work orders are issues to slope grooming and/or snow making departments, which then start the respective processes. These processes can be launched only in the case of favourable meteor-conditions. Also, in a case of congestion on specific slopes, inspectors are informing mountain rescue personnel about the increased risk of injuries. Only this routine needs the coordination of 5 services and three different, independent actors. Given that it is performed continuously, during the day (even nightly, excluding the mountain rescue services) and given that it is highly dependent on the human involvement, high rate of idle time and subjective judgments, it involves great cost and risk of waste of resources in case of inaccurate decisions.

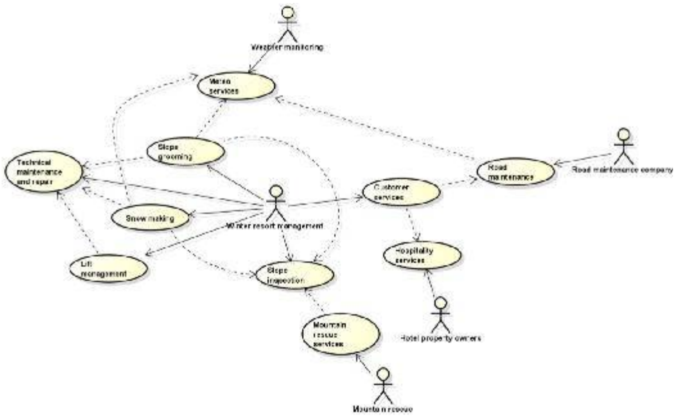


Figure 2. Illustration of the governance and dependence of selected services in Winter Resort Management

This scenario aims the CPS implementation to reduce (if not eliminate) specific human effort in the coordination of services, hence automating the dependencies between them. The following example takes in consideration the enterprises states concept presented at section III.

Sometimes there are enterprises in a winter resort area that need to share some specific management services through the cloud/internet to establish a more collaborative stage in order to answer to common goals as in slope inspection or snow making. To answer such necessity, systems from various enterprises as winter resort hotels, security inspectors and snow making suppliers could rearrange all their available services and resources (e.g. sensors, actuators) to answer to more complex situations where these resources can be shared in a kind of an only one brand to the customer. When this kind of collaborations is established, an advanced stage is reached representing a re-shoring situation that represents the "plasma state". This represents smart enterprises moments that together fulfil specific complex contexts in the best to their business/customers demands. If these collaborations are not necessary anymore there is a kind of "recombination" of each enterprise's systems, where the knowledge related to such collaborations are absorbed to a knowledge base to improve future similar situations. In this case, enterprises come again to a "gas state", which the services of each enterprise keep online ready for new services orchestration if needed.

## V. CPS SUPPORTED BY A MODULAR ARCHITECTURE APPROACH

All the interactions or processes described before should be accomplished through a modular architecture, which each atomic element (e.g. aggregated to a sensor or actuator or a network of those) is the "cyber asset" that is configured for a particular purpose or objective and will be active as a software agent till accomplishes everything to what it was generated for. Each element type of the overall enterprise system has the capability to clone the "cyber assets" as necessary. In a first draft composition of a modular part of a CPS architecture is represented in the Figure 3.

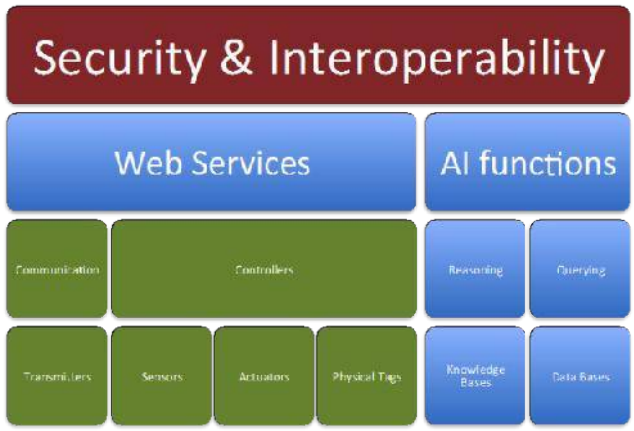


Figure 3. Main elements of a modular architecture (cyber asset element)

Each module (cyber asset) may integrate sensors, physical tags and other smart devices to accomplish sensing information about a determined ecosystem. The data that comes from these various devices is managed by built-in controllers, which then transmit them to particular knowledge bases accomplishing a digital representation of the world. Or on the other hand, such controllers autonomously actuate over other devices that will execute specific tasks accordingly to specific formalised and accessible contexts, representing the shared situational awareness of the physical world (could be physical assets of the enterprise). To accomplish some predictions through simulations, Artificial Intelligence (AI) algorithms will be integrated on such elements as machine learning features able to be installed in function. These features would supply the system of dynamic capacities. All of these interconnectivities and features require a well security, privacy and interoperability policy defined & adequate technical solutions integrated.

## VI. Conclusions and Future Work

The greatest innovation potential of this paper is the integration of various advanced technologies and concepts, such as CPS, sensing enterprise, knowledge management, proactive event-driven computing and smart electronics or embedded systems to offer advanced sensing and decision-making capabilities for enterprises. This paper presents the state of CPS by enabling them with new autonomous decision-making capabilities, moving CPS from sensor and actuator-based systems, to systems with greater intelligence and computational capabilities. This study relies heavily on advanced developments in embedded systems and smart electronics, as enabling CPS with greater capabilities, as well as, pushes the envelope of existing hardware.

These tools increases an enterprise´s market value, by providing a mean of predicting behavioural dynamics of the domain of interest and actuate accordingly. This is achieved by aggregating information and knowledge from sensors, databases and contextual knowledge bases, analysing it and use the output knowledge to support and optimize the decision-making process. An architecture able to self-sense enterprises environment and their own assets is also proposed. In conclusion, an enterprise should be able, not only to acquire information and knowledge in a static way, but it should be, able to re-configure and reprioritize targets of interest, as humans do. This architecture should be able to integrate/disintegrate new components (sensors, actuators, controllers, databases, knowledge bases) in order to fulfil enterprises assets. In other words, enterprises should be able to be reconfigurable to achieve a determined asset, and not limited to the fact of the developments are designed to deal with a limited set of components.

As a future work the authors intend to apply these concepts to the aquaculture domain. In this case the various sensors will be integrated in systems able to potentiate the sharing of enterprises knowledge and services in such way that could enable some dynamicity and intelligence in establishing business collaborations.

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