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Knowledge Management support in Sensing Enterprises Establishment

Joao Sarraipa*. Miguel Ferro-Beca*
Catarina Marques-Lucena*. Ricardo Jardim-Goncalves*

*CTS, UNINOVA, Dep.º de Eng.ª Electrotécnica, Faculdade de Ciências e Tecnologia, FCT, Universidade Nova de Lisboa 2829-516, Caparica, Portugal (e-mail: jfss@uninova.pt; mfb@uninova.pt; cml@uninova.pt; rg@uninova.pt)

Abstract: The Sensing Enterprise paradigm 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 fulfillment 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.

Keywords: Knowledge Management, Sensing Enterprise, Cyber Physical Systems

1. INTRODUCTION

Enterprises, just like individual human beings, cannot survive in isolation or detached from its environment. They exist and are integral part of specific geographic and business communities, and they are both change agents and are changed by many environmental factors that affect them.

The factors, which can affect the success of any enterprise, are various, and they can range from physical location and geographical constraints, to the economic environment in which it operates, to business regulations, political events, among many other variables.

Therefore, in order to successfully operate and deal with current and future challenges, it's imperative that enterprises are able to have a good grasp on the many variables which affect their business environment, and must also be able to proactively prepare themselves for future challenges.

The Sensing Enterprise is a great step towards this challenge, in that, it seeks to make enterprises aware of the context in which they operate by collecting data from a variety of sources, using sensor networks amongst other data sources, processing the data collected and acting upon it, through the use of Cyber Physical Systems, amongst others tools for decision making. On key aspect in enabling the development of a Sensing Enterprise is the Knowledge Management of the data collected. Having access to new and innovative data sources is not sufficient. It is imperative that the acquisition and processing of data translates itself into information and knowledgeable which can assist in decision making within an enterprise.

The present paper proposes a framework for the proper utilization of Knowledge Management in the establishment of Sensing Enterprises.

2. SENSING ENTERPRISE

The FInES community with the advent of the Internet of Things (IoT) created the Sensing Enterprise concept. It was defined in a 2011 FInES Position Paper, and it was described as "an enterprise anticipating future decisions by using multi-dimensional information captured through physical and virtual objects and providing added value information to enhance its global context awareness." (Santucci, Martinez, & Vlad-câlcic, 2012).

The concept refers to an enterprise which can make use of both physical and virtual sensors in order to collect, gather and process information from multiple sources, and then use this information to enhance an enterprise's context awareness. This enhancement will ultimately lead to better and more pro-active decision making, as an improved awareness of the context in which an enterprise operates, by allowing it to anticipate certain events and to react in a more timely way when certain events occur.

As stated by (Lazaro et al., 2012), "The Sensing enterprise concept leverages the power of sensor networks and decentralised intelligence to perform analysis and decision making both in synchronised real and virtual worlds." The usage of sensor networks and decentralised decision making systems creates a change in the boundaries of the enterprise, in terms of where an enterprise gathers and collects data for its decision-making processes.

In the traditional enterprise, most of the data, which is gathered and collected, is usually within its own systems and under its own control. Obviously, the advent of the Internet encouraged a freer flow of data and information outside the confines of an enterprise. However, the usage of such data and information would still be under the supervision of control of either human operators or centralised systems operating within an enterprise. Though, the Sensing Enterprise concept pushes to break these boundaries, by encouraging a direct flow of data and information directly from the source, via the use of sensor networks, as well as, the decentralisation of certain decisions, by providing decentralized systems with intelligence and decision-making capability.

Just like the IoT concept is being applied to a wide variety of sectors, the Sensing Enterprise concept may be freely applied to enterprises operating in multiple areas. Since the Sensing Enterprise concept builds upon IoT capabilities, the concepts are tightly interrelated.

In order to exemplify the concept of a Sensing Enterprise, we shall use a textile manufacturer, which buys certain raw materials (i.e.: cotton, etc.) to manufacture clothing garments.

Without delving very deeply into the inner workings of the fashion industry and textile manufacturing, the success or failure of the textile industry is dependent upon a multitude of factors, which can be social in nature (i.e.: latest fashion trends for a particular season), environmental (i.e.: weather patterns which can affect the production of raw materials, such as cotton), economical (i.e.: supply and demand for materials and labour costs, variations in currency exchange rates, etc.), political (i.e.: conflicts affecting supply routes or indirectly affecting production costs), etc. There may be other factors at play however, the aforementioned ones serve to illustrate the concept.

As seen above, the wide variety of variables, which can affect the operations of an enterprise, can be quite daunting and, in some cases, could be almost humanly-impossible to monitor and process. However, if an enterprise is able to become a Sensing Enterprise, it should then be able to monitor and track a wide variety of data and information, and to use it to generate added value in its operations.

An example of how textile manufacturer operating under the Sensing Enterprise principles would operate could be as follows:

1. Social "sensors" – It is imperative that a manufacturer has demand for the products that it produces. Therefore, in order to ensure that it is in "sync" with the latest trends and fashions, a manufacturer can tap into the existing streams of data provided by social networks, news sites, fashion websites and other information sources related to fashion, in order to ensure that its garments are in line with the latest fashion tendencies.

2. Environmental "sensors" – If a manufacturer is dependent upon the supply of raw materials (e.g.: cotton) from certain regions in the world, it should then have a monitoring system in place in order to keep track of adverse weather conditions, which could possibly affect the supply and/or prices of its raw materials

3. Economic & Political "sensors" – A wide variety of economic and political variables can affect the profitability of company, such as rises in fuel prices, changes in tax regulations, fluctuations in exchange rates, amongst many others. It is extremely important that an enterprise remains vigilant of its economic environment, in order to be able to quickly monitor such variables and react accordingly, or better yet, to predict certain events and take the necessary preventive measures.

4. Manufacturing Sensor Networks and Cyber Physical Systems – One last example is the usage of sensor networks and Cyber Physical Systems within its own manufacturing operations, in order to monitor and control all aspects of its manufacturing operations. The usage of sensor data could then be utilized to streamline operations, develop preventive maintenance practices, amongst many other uses. The usage of Cyber Physical Systems is further detailed in the following section.

The above is meant to be just a brief example of how the Sensing Enterprise concept could be applied, however further aspects could be explored.

3. CYBER PHYSICAL SYSTEMS

A Cyber Physical System (CPS) can be defined as a system which "integrates computing, communication and storage capabilities with monitoring and/or control of entities in the physical world, and must do so dependably, safety, securely, efficiently and in real-time" (Sanislav & Miclea, 2012).

The objectives behind the development of a CPS is the need for integration of "perception, communication, learning, behaviour generation and reasoning" capabilities in order to develop a "new generation of intelligent and autonomous systems" (Sanislav & Miclea, 2012). Embedded systems have existed for many years; however, making these systems intelligent and autonomous requires equipping them with aforementioned capabilities, which is not a small task. Some examples of CPS applications include the following: - Physical infrastructure monitoring and control; - Medical devices and health management networks; - Tele-physical operations; - Vehicular networks and smart highways; - Electricity generation and distribution; - Robotic manufacturing; - Aviation and airspace management; - Defence and aerospace systems.

As shown above, the areas of application of Cyber Physical Systems are varied, however, as an example, the focus will be shifted onto the manufacturing sector.

The usage of automation systems and robotics is quite prevalent in manufacturing. Depending upon the type of industrial sector, there is a quite high likelihood that most factories operating today rely upon either type of these systems. However, regardless the level of automation already present in any sector, the trend towards a greater integration of CPS is gaining momentum driven by the vast amounts of data generated by manufacturing processes & tools which go either uncollected or unprocessed, as well as, the need for greater coordination of manufacturing processes to reduce downtime and inefficiency, amongst other factors.

The deployment of sensor networks on a manufacturing line, to gather and collect data, as well as the exchange of data between manufacturing tools and other enterprise systems, would create a network between them. By adding some level of computational intelligence into manufacturing tools and robots, would transform them into cyber physical systems.

This sort of transformation would enable innovations such as allowing manufacturing system "to communicate with every step of production in real time, maintaining a constant flow of information to track new orders, raw materials availability, shipments, production quotas, supply chain networks, and human resources and labour management." (Lane, 2013)

Additionally, the integration of the manufacturing data collected by sensor networks could be utilized to streamline production processes, reduce downtime of manufacturing tools, etc.

Although much of the technologies to develop Cyber Physical Systems already exist, the complexity behind such systems requires extended research work in a variety of disciplines including, but not limited to, networking, systems theory, software engineering, sensor technologies. Even though the disciplines related to CPS are varied, they can however be grouped into the following general research areas: 1) New approaches related to formalisms and architectures which allow for interoperability between the various sub-systems within a CPS; 2) New frameworks, algorithms and methods related to time and event-driven computing software; 3) New models, algorithms and tools to verify and validate software components and the entire CPS.

Nevertheless, there are many ongoing efforts related to CPS already in place, both in research and in industry (i.e.: General Electric's "Industrial Internet" (Van Lier, 2013), as the potential benefits and cost savings provided by CPS far outweigh the effort and investments required.

4. KNOWLEDGE MANAGEMENT

There is a growing recognition in the business community about the importance of knowledge as a critical resource for organisations (Matthews & Harris, 2006). Individuals and companies are obliged to focus on manage and enhancing their knowledge asset in order to innovate (Matthews & Harris, 2006; Metaxiotis, Ergazakis, & Psarras, 2005) and survive in the current competitive markets.

Knowledge is the human expertise, which is normally stored in a person's mind, gained through experience, and interaction with the person's environment (Sunassee & Sewry, 2002). The term knowledge is also used to mean the confident understanding of a subject with the ability to use it for a specific purpose if appropriate (Engeström, 1999).

Knowledge can be represented in machines. It is composed by specific sets of formalized information. It represents a message that could contain relevant meaning, implication, or input able to be used for decision and/or action. Information comes from both current communication and historical processed data or 'reconstructed picture' sources. Data is the storage of intrinsic meaning, a mere representation, which normally is represented as symbols that represent properties of objects and their environment (Ackoff, 1989; Liew, 2007).

In essence, the purpose of data is to provide input to contextualize specific information, which when acquired and retrained into appropriate knowledge bases is able to aid systems in making decisions and/or solving problems or realizing an opportunity. (Liew, 2007).

Knowledge acquisition is the process of extracting, structuring and organizing knowledge from one source, usually human experts. However it could be related to specific sets of data sensors or from social web data. When it is addressed, the knowledge extraction from data as texts (e.g. social web data), it is named Knowledge Discovery in Data (KDD). KDD is the non-trivial process of identifying valid novel potentially useful and ultimately understandable patterns in data (Fayyad, Piatetsky-Shapiro, Smyth, & Uthurusamy, 1996). KDD arises from the necessity to digest large volumes of data. As data volumes grow dramatically, manual data analysis is becoming impractical in many domains (Duru, 2005) since it is not expected that a human can process millions/billions of data records. Focusing on that, many efforts have been made to automatically or semi-automatically identify patterns in large data sets. Novel research fields such as machine learning, artificial intelligence, performance computing, etc. support these efforts.

The application of the mentioned research field aims to find unpredicted relationships in large data sets and summarize the data in novel ways. The identified patterns may potentially be useful information that cannot be, at least easily, identified by humans. By identifying those patterns and making them human understandable, this potentially useful information can result in knowledge to be used in enhanced decision-making purposes, thus in business purposes.

Knowledge Management (KM) is the process of capturing the collective expertise and intelligence in an organization, using it to promote innovation through continued organizational learning (Carneiro, 2000). It is related to the supervision of the knowledge creation life cycle.

Knowledge creation can be considered as the transfer, combination, and maintenance of the different types of knowledge, as user practice, interact, and learn (Nonaka & Takeuchi, 1997). Knowledge can be created through social interactions between individuals or through the KDD and shared in information systems (Pei, 2008).

Knowledge Management Systems (KMS) are seen as technological enablers to achieve effective and efficient KM. The primary goal of KMS is to bring knowledge from the past to bear on present activities, thus resulting in increased levels of organizational effectiveness (Lewin & Minton, 1986)(Stein & Zwass, 1995). Nowadays, KMS is the technological part of KM initiative that comprises person-oriented and organisational instrument target at improving the productivity of knowledge work (Maier & Hädrich, 2006). They are designed specifically to facilitate the sharing and integration of knowledge, which finally could be used to validate business purposes or sensing enterprise establishment.

5. FRAMEWORK FOR THE ESTABLISHMENT OF SENSING ENTERPRISES

The proposed framework intends to serve as a guide for the establishment of sensing enterprises. It indicates or proposes what kind of characteristics should be addressed and how they would interrelate to build a system able to give support to the sensing enterprise concept materialization.

In the business realm, the study of the business environment in which an enterprise operates is defined as "context analysis". The business environment analysis is important to identify the sensing enterprise factors that an enterprise has to handle and which defines and characterizes the main business characteristics that will direct the key (business) impact factors. These sensing enterprise factors were defined from what Enterprise Environmental Factors are but focused on the Sensing Enterprise general characteristics. Thus, such factors are related to existing conditions that can influence the successful establishment of a Sensing Enterprise. Consequently, some of the aspects, which are the subject of attention in the referred context analysis, may include the following:

1. Trend Analysis – The focus of trend analysis is on the overall macroeconomic variables, which affect the business environment where an enterprise operates. This may include the analysis of the political, economical, social, demographic and technological trends.

2. Competitor Analysis – The objective of this type of analysis is to gather information on existing and possible competitors, and how their activities may affect an enterprise.

3. Opportunity and Threat analysis – This dimension determines possible business opportunities or business threats. This analysis may build upon the trend and competitor analysis, or it may come from studying other types of data and information (ie: disruptive technologies)

4. Organizational analysis – Lastly, the focus of context analysis is internal, as it determines whether an enterprise has the required resources (human, financial, technical, etc) in order to take advantage of the business opportunities, or to face the potential business threats identified above.

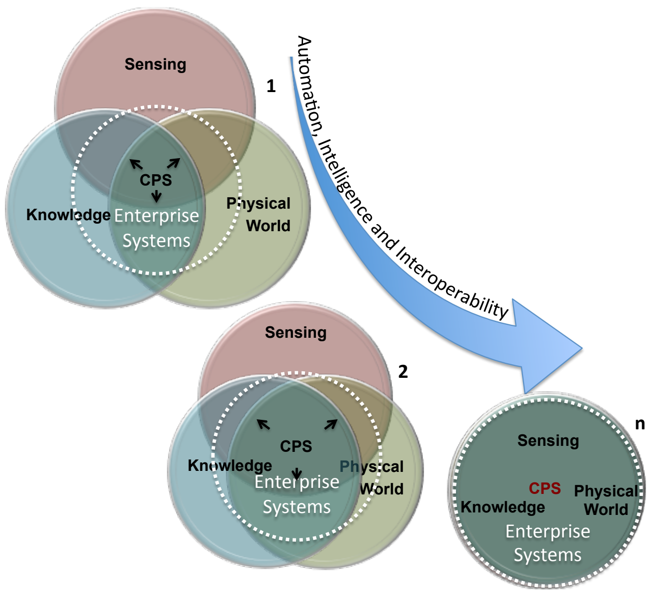

Fig. 1. Cyber Physical Systems in action to Sensing Enterprise establishment

Traditional context analysis, was usually performed by internal employees (i.e.: business analysts) of an enterprise, usually aided by external business consultants, who then relied on the research departments of their consultancy firms for access to relevant business data related to the economic environment, competitors, etc. Apart from being expensive and time consuming, traditional methods often relied on data which was limited in its availability and not very frequently updated. The advent of Internet, Social Media and Big Data brought with it a new whole variety of data sources, which can possibly enable a more in-depth and accurate context-analysis for any enterprise. Some of the possibilities include, but are not limited to the following: 1) Analysis of Social Media for customer sentiment and track online reputation of an enterprise and its competitors; 2) Analysis of Search analytics for business, economic and social trends: 3) Access to wide variety of open data sources, statistical data, etc.; 4) Ability to use web crawlers to extract more specific information and data from other websites; and 5) Access to real-time data from sensor networks, IoT data, etc.

While the new data sources provided by the new digital age may not replace proper context analysis and the role of business analyst, it can however, facilitate their work and provide further insights which otherwise would not be available, if only traditional data sources were to be utilized.

5.1 Sensing Enterprise Establishment

In a sensing enterprise establishment it is necessary to integrate three main enterprise dominions: the physical world; knowledge and sensing, where CPS is the catalyst of such establishment (Fig. 1).

The phase 1 of Fig.1 illustrates the introduction of CPS into an enterprise system. It starts to aggregate a small part of the "sensing" and knowledge of an enterprise, which is related or acts over a part of its physical environment. Using the example presented before about a textile manufacturer, the sensing can be related to the ability to acquire information about fashion trends and understand its implications to the amount of stock of its raw materials. Thus, the enterprise system has to handle the data coming from such sensing, which can be simple data if comes from sensors or complex information if it comes from social media sources. Then, this information has to be modelled and stored in appropriate knowledge bases defined specifically for this purpose (e.g. ontologies), which after undergoing specific reasoning would accomplish the understandability of the context situation. As a result of understanding the collected info, the enterprise system could react increasing or decreasing the demand for raw materials, which would influence the physical part of the enterprise (raw materials stock). The phase 2 of Fig. 1 illustrates that the CPS of the enterprise system already aggregates more "sensing" features. Ideally the CPS manipulates all of the enterprises' sensing and knowledge, which would be represented by full coincident dominions (phase n – Fig. 1).

The key towards reaching a fully automated stage depends on the ability of a system to handle knowledge. It also has a direct influence on its intelligence and interoperability skill as represented in Fig.2.

Turnitsa and Tolk defined in (Turnitsa & Tolk, 2008), the Knowledge Representation Requirements Model (KRRM), which shows the increasing needs for greater ability to represent knowledge, and also gives the levels of conceptual interoperability that may be reached if the requirements are met.

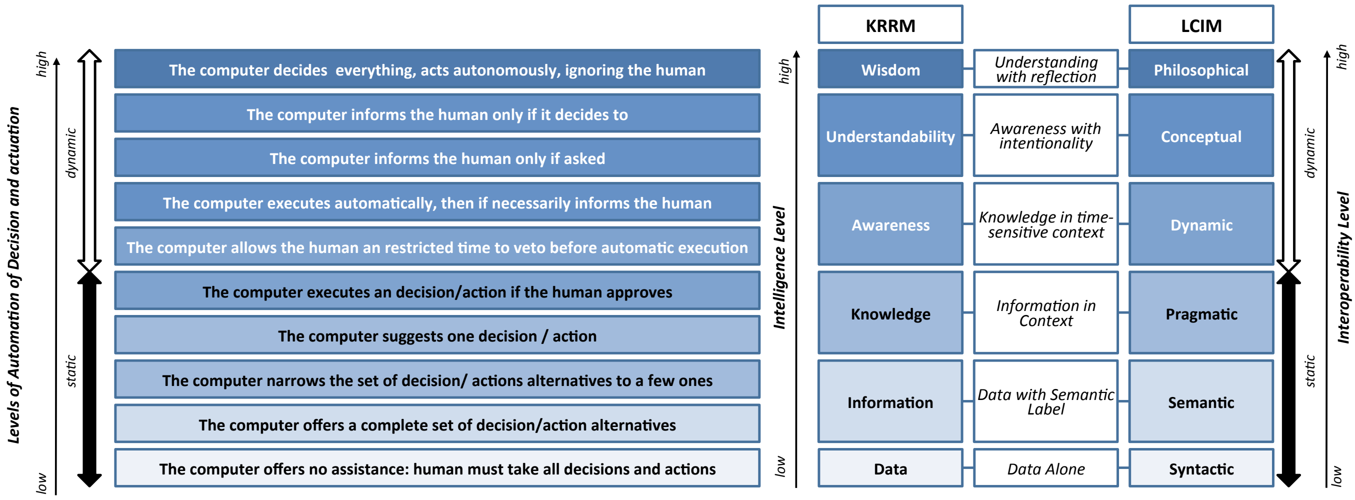

Fig. 2. Sensing Enterprise Systems Automation, Intelligence and Interoperability Levels.

Such conceptual interoperability levels are defined by the Levels of Conceptual Interoperability Model (LCIM) model, which shows the different levels of interoperability that may exist between systems, from technical interoperability through conceptual interoperability (Turnitsa & Tolk, 2008)(Tolk, Turnitsa, Diallo, & L. S. Winters, 2006). A system that is able to operate at the Syntactic Interoperability level is only able to process data, thus requiring human intervention for all decisions and actions. As the Interoperability and Intelligence levels of a system increase, so does its level of automation in its decision making. Currently, many systems are able to operate automatically in some dynamic situations, meaning that they have reached the Awareness level of intelligence and are able to operate at the Conceptual Interoperability level.

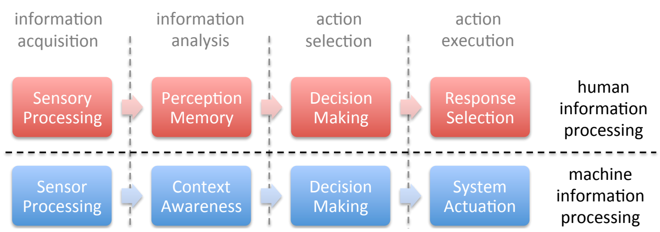

Fig. 3. Human and machine information processing (Parasuraman et al.,2000)

Decision-making can be regarded as the cognitive process resulting in the selection of a specific resource or action among several alternative scenarios. Every decision making process produces a final choice (Reason, 1990). Simon at 1960 described the decision-making process as consisting of three phases: intelligence, design and choice (Simon, 1960). Intelligence is used in the military sense to mean searching the environment for problems, that is, the need to make a decision, which represents to have context awareness. Making decisions with awareness will reduce the effort to coordinate tasks and resources by providing a context in which to interpret utterances and to anticipate actions (Gutwin, Greenberg, & Roseman, 1996). These statements underpin the machine information processing specification, which has a direct relation to the human information processing structure (Fig.3).

Sentiment analysis seeks to identify the viewpoints, namely positive and negative opinions, emotions and evaluations. Most of the observed work on sentiment analysis has been done at a textual level One application example is to classify a YouTube movie as "thumbs up" or "thumbs down". However, tasks such as multi-perspective question and summarization, opinion-oriented information extraction, and mining product reviews require sentence-level or even phrase-level sentiment analysis. (Pang & Lee, 2004; Wilson, Wiebe, & Hoffmann, 2005). One major obstacle to achieve sentimental analysis is the fact that opinions are expressed in many complex ways (including sarcasm and metaphor), and there is much unrelated and potentially misleading text such as plot synopsis (Whitelaw, Garg, & Argamon, 2005). In (Wilson et al., 2005) another obstacle to achieve sentimental analysis is identified. They considered that a typical approach to sentiment analysis is to start with a lexicon of positive and negative words and phrases. However, sometimes positive/negative prior polarity words are not used to express positive/negative sentiments. To get a correct analysis, it is necessary to consider the phrase level.

It is therefore understandable that increased levels of autonomy for decision making systems will require an increased level of context awareness, and, ultimately, increased sentiment analysis capabilities, with the goal of achieving the Understandability and Conceptual levels of Knowledge and Interoperability.

6. CONCLUSIONS

The need for proper Knowledge Management is essential in the development of a Sensing Enterprise, and the proposed framework demonstrates how it can be incorporated in the process of turning collected data, into valuable information and knowledge. The framework demonstrates that just like humans, machines must go through a cycle of “sensory” processing, which translates raw data, into actionable decisions. This process is vital to enable the decision making capabilities of the Sensing Enterprise, and empowering the Cyber Physical Systems, which assist them.

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