A Software Framework for Supporting Ubiquitous Business Processes: An ANSI/ISA-95 Approach

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***Abstract* — Nowadays, organizations to survive competitively they need to be, innovative and efficient. The way the Internet has been expanding along with other technological changes is leading us to a future in which all the objects that surround us will be seamlessly integrated into information networks. The possibility to implement concepts related with the ubiquitous computing in the business process-level will influence how they are designed, structured, monitored, and managed. One of the most remarkable possibilities of ubiquitous computing can be the real-time monitoring of a particular business process: it should be possible to analyze the flow of materials and information, identify possible points of failure or improve energetic efficiency with a small delay on they occur in reality. Currently, there is no direct and automated link between ubiquitous business processes descriptions and their physical executions which, frequently, promotes the occurrence of a discrepancy between the planned modes of operation and the executed ones. The ubiquitous business processes will enable a narrowing between the real (objects) and virtual (models) world and the possibility to create adaptive business processes that can predict failures, adapting themselves to changes in the environment is an attractive challenge. In this PhD thesis, we will propose a new software framework to monitor real-time executions of ubiquitous industrial business processes.**

Keywords: software design, computer science related discipline: information management, management related discipline: information systems management

I. INTRODUCTION

The first reference to ubiquitous computing dates from 1993, when Mark Weiser projected the future as he imagined: “The idea of ubiquitous computing first arose from contemplating the place of today’s computer in actual activities of everyday life” [1]. Since then, there have been tremendous developments in technology, many new concepts have appeared, others suffer various changes, however Mark Weiser’s words still hold true. The effort expended in the study of ubiquitous systems and technologies that support them has gained considerable interest and has been the target of several advances, whether in academic or in industrial fields. In another study [2] is also noted that “The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it”.

In addition to the benefits inherent from the technological advancement and deployment of ubiquitous computing, users of these systems should be key elements, acting, interacting and improving these environments. Ubiquitous computing is more than just allowing the various devices (in a common environment) to communicate/interact among them. It also consists in the way they do it, in the way they interact with users and how they can help users achieving their goals [3].

The user satisfaction is a key element for the success of ubiquitous systems; however, the use of ubiquitous computing not always aims the satisfaction of a single user, but the satisfaction of an organization, a group of people, a value chain or a business. The use of ubiquitous computing in organizations has been growing, not only for employee satisfaction, but also to improve work methods, processes, efficiency, to reduce production costs, etc. Ubiquitous computing has the capacity to improve the way business processes are (re)designed and executed, which in turn will bring more competitive companies and better economy efficiency by allowing these same companies to invest more in technology development [3]. It is therefore a win-win situation, if applied properly.

In organizational contexts, it is frequent the occurrence of discrepancies between the planned modes of operation of business processes and the executed ones. As an example, in an industrial company we may need to monitor and manage in real-time the production status. This monitoring and management tends to be difficult when recurring to current business processes models, because their observation relative to the real operations is done long after their executions and thus important data may be missing as well as reaction time may be surpassed. There is a big time delay in the perception of problems, by management teams, and also delays in reacting to them, which can lead to serious problems and costs that should be avoided. Additionally, the human-reported data tends to be not so accurate and with lower scope as data collected directly from the business process elements. This data gaps endanger the ability for organization to manage based on concrete and detailed facts. Without the constant monitoring of business processes, in all their execution phases, it becomes impossible to manage them adequately. Hence, it is necessary to investigate how to

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benefit from the ubiquitous computing principles to support the monitoring of business processes. It is expected that this new approach would influence how business processes are designed, structured, monitored, and managed. We need to adequately design all the concepts to trigger, store, and manage all the data relative to the business process execution. This design should be a consequence of each organization requirements and can be materialized on traceability concerns and policies deployed into the design and execution of business processes. We need a software framework to design solutions capable of linking these two worlds.

II. STATE-OF-THE-ART

To support the ubiquitous computing vision that Mark Weiser projected in 1993, beyond any technological evolution, innovation must continue because the paradigm of ubiquitous computing is different from traditional computing paradigms. Imagine a closed environment where all objects present have the ability to communicate; a ubiquitous system that supports this environment will have to bear not only the heterogeneity objects but also the possible different forms of communication. If it is already difficult to conceive the ubiquitous system for a closed environment, imagine for an open environment, where the objects appear and disappear randomly. In these types of systems we now have an environment not only diverse but also decentralized, where various types of objects communicate using different technologies. The benefits inherent in the use of ubiquitous computing were readily assimilated by organizations that seek to optimize their processes, to reduce costs, and by organizations that want to continuously improve and generate profit. Strassner [4] argues that "when companies plan to adopt a new technology, they want to know the business impacts in advance". This capability allows companies to better control their processes, avoiding harmful situations (e.g. the bull-whip effect), thereby improving the flow of material, the flow of information, eliminating the production to stock, and excess production. Supply chain inefficiencies can waste up to 25 percent of a company's operating cost [4].

The bull-whip effect is very harmful to any organization, and the use of "pillows" such as the creation of stocks is not certainly the best strategy because it increases the company costs. It is in cases like these that the ubiquitous systems have a role to play, arming organizations with ubiquitous processing power, allowing them to create a harmony within the value chain, and coordination between the flow of materials and the flow of information.

Recently, Lupiana [5] proposed a taxonomy to distinguish ubiquitous environments. He categorized UbiComp environments in two major classes: Interactive and Smart environments. In turn, Chen proposes an ontology (SOUPA: Standard Ontology for Ubiquitous and Pervasive Applications" [6]) for the creation and development of ubiquitous/pervasive applications.

Regarding the development of applications for pervasive information systems, it should be noted the article "Model-Driven Methodologies for Pervasive Information Systems Development", where the authors report that "we become aware of the presence flow and processing of information, not only by the individual computing devices, but also with a more deep significance, by the overall system that emerges from the interactions of all the computing devices, linking them together in a coherent fashion" [7], which values the need to have a holistic view.

A. *Business Processes*

In day-to-day activities, organizations interact with multiple and distinct entities. These entities can either be part of the internal organizational structure (e.g. in case of large organizations) or external agents to the organization, but playing an important role, such as suppliers, customers, etc.

For all these entities to function properly and in harmony it is necessary to establish processes, tasks and activities so that everyone can work with a common goal. Good communication is a key element to the various entities that communicate with each other. It was based on these assumptions that business processes arose. They plan to serve a set of processes, tasks, and activities that must be carefully performed by various entities, at indicated times and in a specific order. The main objective of a business processes manager is to have a holistic view of the entire organization (from suppliers and raw material to customers and finished product) in order to define a set of processes that aims overall improvement, cost reduction, waste reduction, reworking, and productivity. The processes of an organization reflect the way tasks and procedures are performed, and can (and should) be redesigned whenever possible in order to ensure continuous improvement.

A business process is triggered by a business event, and aims to delineate a set of procedures/activities to be performed by people, machines and/or computers. These participatory elements have distinct roles and objectives throughout the process course. A process consists in a specific order of work activities across time and place with a beginning, an end and clearly identified inputs and outputs [8]. When modeling business processes, we need to take care of several items. Two key issues are how much detail and how to handle uncertainties. The level of detail will allow us to know how deeper we want to go when decomposing the process. The way we expect/control uncertainties, will allow to have mechanisms to control the process. The uncertainty is one of the main reasons why the procedures deviate from what was previously stipulated [9].

Monitoring consists in collection, compilation, analysis and presentation of data that reflects how a particular business process is being executed and managed by different agents (from people to machines). It is easily verifiable that trough monitoring one can know if a process is or is not being properly executed, or whether it is well or poorly modeled. The real-time monitoring allows for timely decisions that can prevent a future malfunction of the processes. A monitoring system observes the behavior of other system and checks if it is consistent with what is expected, with a given specification [10].

The topic of real-time monitoring is very controversial, starting immediately from the definition of the word "real-time".

B. Ubiquitous Business Processes

Again, we emphasize that the ubiquitous systems have a very important role in monitoring business processes. With the use of smart items, we can follow the state of the products. Huang [11] developed and implemented a practical solution for monitoring business processes using ubiquitous systems. In this particular case were used RFID tags to easily monitor the inventory of an organization. He analyzed and proposed the best places to put the antennas that would read the RFID tags, where to place the tags, etc, in order to have a real-time inventory management.

In another research, Zhang [12] describes a smart kanban system using RFID technologies for shop-floor management and several relevant real-time manufacturing data capturing cases using RFID, wireless production lines and wireless shop-floor inventory management. In this particular case, the use of RFID tags within kanbans is a very interesting concept because it allows monitoring a lot of articles along the chain at a low cost, because the RFID tags are reused since they are an integral part of the kanban.

A practical example of a monitoring system was developed and presented by Huang [11], which proposes an infrastructure to implement RFID for product tracking and monitoring. They also propose formulas for comparing the actual state of the process compared with planed one.

III. RESEARCH OBJECTIVES AND METHODOLOGICAL APPROACHES

A. Research objectives

The everyday work in a large automotive company, allows us to experience and witness certain events which sometimes raise doubts and questions that are not easy to answer. This research proposal follows exactly this perception from the reality and of the experienced events, which, inserted into a dense organizational structure, sometimes becomes so obscure and dissimulated, that are unnoticed by who has the capacity to take decisions and is responsible for the design of business processes, which are so vital to any company.

The ANSI/ISA-95 standard [19] consists of models and terminology, and addresses the issue of integration of different information systems, software applications, Programmable Logic Control(lers) (PLC), etc, in industrial systems. The ANSI/ISA-95 is divided into 5 parts: (part 1) models and terminology (published 2000); (part 2) object models and attributes (published 2001); (part 3) activity models of manufacturing operations management (published 2005); (part 4) object models and attributes of manufacturing operations management (under development); (part 5) business to manufacturing transactions (under development).

This standard plays a critical role in our research, since we will adopt an approach compliant with the part 4. We will identify which kind of information needs to be exchanged across the several organizational layers for user requirements purposes and also for database and software development. Our software framework will allow the design and execution of interfaces, assuring the correct flow of information between the enterprise information system and the manufacturing operations system.

Fig. 1 illustrates the different structural/hierarchical levels existing in a typical industrial organization. The ANSI/ISA-95 standard organizes the different organizational layers and provides standard protocols for exchanging information, thus facilitating the flow of information through the different layers of the organization:

- In level 4 (business related activities), activities are not directly related to production (long term planning, marketing, sales, procurement). At this level we can find ERPs, where business and logistics planning occurs.

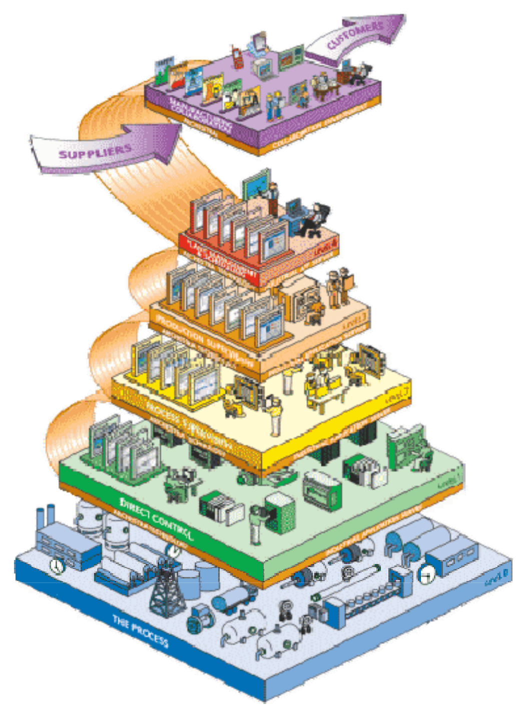

Fig 1: ISA Model (adapted from [18])

• In level 3 (manufacturing execution system) work flow activities produce the desired end products. Consists of several activities that must be executed to prepare, monitor and complete the production process that is executed in the lower levels (0 - activities of monitoring, supervisory control and automated control on the production process; 1 - activities involved in sensing and manipulating the physical process; and 2 - actual physical process). Examples are: detailed scheduling, quality management, maintenance, production tracking, etc.

The time frame adopted in level 4 can be in days, months or even years. As long as we go down into the levels, the time frame changes to days, shifts, hours, minutes or seconds. At level 2, the time frame can be sub-seconds or milliseconds. Within this PhD work, we will address levels 3 and 4, which relate to business processes. We will also address level 2, in order to interoperate ERPs to the PLCs, in order to decompose the business processes and monitoring them at level 2. Our research objectives are:

• Based on models of existing business processes (requirements specifications from the software point of view), we intend to develop a method to decompose the business processes allowing the definition of where and how real-time monitoring should be done. This method will also enable the formalization of the ubiquitous nature of the business processes.

• Based on concepts from the ubiquitous computing paradigm, we intend to develop a software framework to support the monitoring of the industrial ubiquitous business processes executions. We will adopt behavioral and architectural patterns to support the interoperability of sub-systems.

• To validate the proposed method and framework in real scenarios of industrial production environments from Bosch Car Multimedia factory plant.

B. Methodological approach

Design Science Research (DSR) [13] will be adopted as the main research method. One of the main reasons that led to the choice of this method is that its main objective resides in solving real problems. DSR is a normative and prescriptive method, and the researcher is usually pragmatic. DSR is elaborated trough the relationship between two main activities: build/design and evaluate, where researchers recur to kernel theories in order to develop artifacts and then demonstrate that they can be built [14]. These kernel theories frequently derive from disciplines outside of information systems area, and suggest novel techniques or approaches to IS design problems [20].

This model (Fig. 2) of "construction" and "evaluation" has been used in the past to develop new knowledge through the construction and performance evaluation of new artifacts.

Development, *Evaluation*, and *Conclusions* stages can be iterative; i.e., the result of each stage can trigger the start of another cycle. The *Circumscription* process is especially important because it generates understanding that could only be gained from the specific act of construction; it assumes that every fragment of knowledge is valid only in certain situations [13].

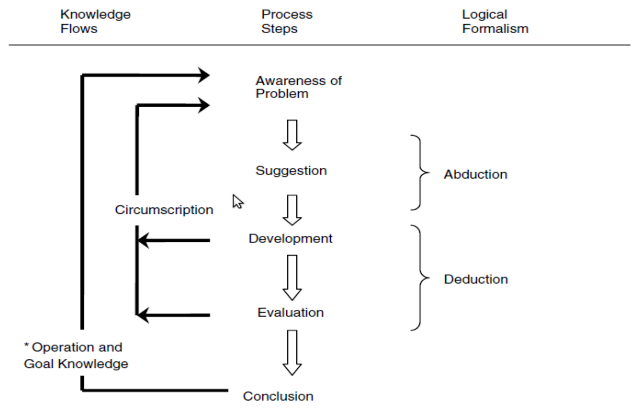

Fig. 2: The General Design Cycle [13]

Once the artifact is finished, it has to be returned to his environment in order to be studied and evaluated in their application domain [15]. For Hevner the development of an artifact relies on kernel theories, which are applied, tested, modified, and extended through the creation of artifacts. Although based on existing theories, DSR also contributes to the "construction of new theories" or to the improvement of existing ones [13]. Better theories are one of the possible outputs of DSR, as shown by Hevner and Chatterjee [16].

DSR always seeks a solution to solve practical real world problems, and IT artifacts are the end-goal of any design science research project, and are broadly classified into: constructs (vocabulary and symbols); models (abstractions and representations); methods (algorithms and practices); instantiations (implemented and prototype systems); better design theories.

Vaishnavi considers constructs as the conceptual vocabulary of a problem/solution domain and they appear during the conceptualization of the problem, and models as a set of propositions or statements expressing relationships among constructs. Methods are objective oriented, and consist of a step of steps used to execute a task. Finally, instantiation is the next step, the accomplishment of the artifact in an environment [13].

Samuel-Ojo [17] refers that "research in the information systems field examines more than just the technological system, or just the social system, or even the two side by side; in addition, it investigates the phenomenon that emerges when the two interact". It is not easy to design useful artifacts; sometimes the researcher needs to be creative because existing theories in those specific domains areas are insufficient. These artifacts have to create direct impact on organizations and in society in general.

IV. PAST WORK AND PRELIMINARY RESULTS

We have already been involved in the creation of real-time monitoring systems at Bosch Car Multimedia plant. We have adopted the DSR approach in two projects whose aim was to develop systems for real-time data acquisition and information delivery. The acquired data was also used to trigger alarms and measure real-time reaction times.

The *Milk Run Realtime Information* (the first DSR execution) consisted of a real-time monitoring system for the supply convoys of the manufacturing (manual and automatic) production lines. This project meant to monitor the supply time of production lines, by the convoys. Monitoring was done upon leaving the warehouses, and controlling was carried out in various points of the route. Whenever time deviations occurred in relation to the planned, alarms were automatically triggered and the reactions times (by interventions teams) were also calculated and stored for future use.

In the *Realtime ANDON* project (the second DSR execution), a solution for real-time monitoring of manual insertion lines was developed. These lines worked for 24 hours a day, in 3 shifts. To accomplish this project, several points of control along the production line were adopted, by using SOAP protocol to communicate with the central server, informing the location and identification of the products. We have used infrared technologies to read the serial number of the unit. Taking into account: (1) the production time of each product (a line, during a shift, may produce several types of products with distinct production times); (2) the production plan defined, for each shift; and (3) the production pre-defined breaks; we have been able to calculate, in real-time, the production rate of the line and also to show, either in time or units, the delay/advance checked against the planned/expected production plan.

Both solutions caused impact on the organization, and helped, not only to find faults, but also to help improve the production plan. In the second project, it should be noted that on the beginning, it was received with some reluctance from the production line workers, because their work was being monitored and measured constantly, and published in real-time to everyone in the factory trough big TV screens. However, we found that the people themselves began to use the system in order to know, in real-time, the amount of unities they had to produce to finish the shift, and to compete with neighboring production lines. Using the data collected by this monitoring system, it was also possible to recalculate the production times of several products and automatically calculate the quick change over (QCO) between products, and thus improve the production planning.

In both projects open source software (like Apache, MySQL and Linux) was used. The programming languages used were Perl and PHP. The communication protocol used between the control points and the server was SOAP. During the execution of the first DSRs, the experience with all these technologies for implementing those two projects has enabled us to get real knowledge about the problem domain and also to start the effort to design the software framework that will be further developed and explored in future projects.

V. FUTURE WORK AN D EXPECTED RESULTS

In the near future, we will start the formalization of the software framework based on the first two DSR executions to enable the adoption of new mechanisms in the next projects to be developed. Only after the formalization of the first perception of the software framework we will be able to come-up with some new behavioral and architectural patterns and also with some technological insights that we may discover to be innovative and efficient. The process of literature review will allows us to base the writing of our scientific contributions on solid arguments. We intend to publish our contributions in reputed journals/conferences: EUROMICRO Conference on Software Engineering and Advanced Applications (SEAA); International Conference on Information Systems Development (ISD); AIS European Conference on Information Systems (ECIS); International Journal of Computer Integrated Manufacturing (IJCIM); and International Journal of Enterprise Information Systems (IJEIS). Publication and/acceptance on this set of journals and conferences aims to validate the research quality, the quality of the articles, the scientific contribution and the recognition of the developed work.

VI. CONCLUSION

The importance of modeling business processes in any company is of utmost importance nowadays. With recent technological advances, such as the ubiquitous computing, the potentialities from these advances may come, in some way, to affect the way business processes are modeled, monitored, and executed. Ubiquitous computing, and all the advantages/disadvantages that come with it, are not yet completely known in the industrial world. Despite not having much work done in the field, there is already some knowledge and concern over this issue.

One of the main concerns identified, resides precisely in the absence of real case scenarios with economic impact in organizations. This is actually one of the points to improve, in order to change some existing paradigms in organizations, opening new horizons and promoting innovation; otherwise they risk being overtaken by competition.

Ubiquitous computing will then empower organizations with new resources, which may, when properly used, help to monitor their industrial processes, providing relevant information to whom right, in real-time. For it to become real, it is necessary to cut the existing business processes, i.e., decompose them, in order to know how and where monitoring should be done and, more importantly, how and by whom, by which decision agents. It is necessary to formalize the ubiquitous nature of the business processes.

This new understanding of formalization of the ubiquitous nature of the business processes, and how they must be implemented and executed, allows the creation of a software framework that can monitor real-time executions of ubiquitous industrial business processes.

This proposal seeks to validate this software framework, in real settings, by practical application, because its contributions, if advantageous, could be directly incorporated into companies' best practices. The proposed research method, DSR, fits gracefully in those, which are the premises of this research. We propose to find a practical solution to real problems, by building IT artifacts, in this case, a software framework.

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