Using Business Process Modeling for the Integration of Wearable Computer Systems in MRO Applications

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Abstract **– Maintenance, repair and overhaul (MRO) processes supported by mobile and wearable computers are increasingly replacing paper-based processes. Since wearable computers can be worn on the body and operated hands-free, they bring computer support directly to actual workplaces. This results in a closer integration of mobile IT support into work processes. Thus, including the design of such computer systems within the Business Process Model of a company is a logical step. In this paper, we describe our approach to integrating the *Interaction Constraints Model* (ICM) – the result of our previous research – into a commercial software tool for Business Process Modeling (BPM). We illustrate the integration of the design process of mobile and wearable computer systems into the Business Design Process of a company. In a case study, we illustrate how the ICM and the underlying method for design re-use can be adapted to and integrated into ARIS, one of the leading commercial BPM tools.**

I. INTRODUCTION

Wearable computers are being applied more and more in industrial applications. They offer “hands-free” IT support for processes in which both hands are needed, but interaction with a computer system is still required. By wearing the actual hardware of the computer system and by interacting with the machine via speech, wearable computers bring IT support directly to the workplace without interrupting or disturbing the actual work processes.

Developing wearable computer systems requires a sound understanding of the work processes that need to be supported by the system, as well as the business processes at the backend of the IT environment in the company. Furthermore, a wearable computer project involves participants of many different backgrounds, such as software developers, hardware experts and the domain experts for the application at hand. Thus, it is beneficial if a clear and understandable description of the business processes to be supported by wearable computers exists.

Business Process Modeling (BPM) is one way to describe processes in a company. In this paper, we describe and illustrate our approach to extending BPM to include the views relevant for the development and application of wearable computer systems for supporting maintenance, repair and overhaul (MRO) applications. We describe how we combined an interaction model from our previous research with experience of real world applications and how we transferred this research model into a commercial BPM tool.

A. Wearable Computers in Industrial Applications

Wearable computers can be worn on the body or are integrated into clothing and at least temporarily offer hands-free interaction, mainly via head-worn displays and speech technology. Such systems offer computer support everywhere the user moves or works, i.e. at the very place where the IT support is needed. In contrast to kiosk-like terminals, they do not interrupt or disturb the actual work process, but reduce media breaks and resulting errors, e.g. there is no data transfer between paper-based lists and digital storage. Compared to laptop or handheld computers, wearable computers are far more unobtrusive and can support the user more naturally.

Examples for the use of wearable computers in industrial applications are warehouse activities and maintenance processes. In the first example, so-called pick-by-voice solutions on wearable computers guide the picker in a distribution center to the products on the shelves (see Figure 1); in the latter, the user can see inspection lists on a head-mounted or body-worn display (see Figure 2).

Fig. 1. Vocollect Talkman pick-by-voice system

Fig. 2. Xybernaut MA V wearable computer

B. Interaction Constraints Model

In previous research [1], we developed an interaction model that could map work situations, which are to be supported by speech-controlled wearable computers, with situations from other applications and domains. Thus, this model helps in retrieving information on the viability of specific interaction means based on previously acquired experience. Underlying the model is the idea to define work situations based on the constraints that occur and their influence on using the wearable computer.

The developed *Interaction Constraints Model (ICM)* maps constraints of specific situations, in which mobile IT support is needed, to user interface components that may be incorporated in the system design. Due to the nature of industrial applications, these situations mostly are work situations, i.e. situations in which users of mobile and wearable computers work at a specific location on a worksite and have to perform a task.

This means that the user's interaction with the device is not only constrained by the physical location, but also by the activities that are supported by the device. The importance of location and activity derives from the need to establish IT support at the actual worksite via wearable computers. The fact that the need for computer support has moved from a central location, such as the desktop or a kiosk-like computer, to "anywhere" on the worksite requires that the location of the mobile worker be taken into account during the design process. The fact that mobile IT support helps to accomplish another activity - the actual task to be accomplished – requires that we view interacting with mobile IT support only as a secondary task. Thus, this secondary task has to be unobtrusive with respect to the primary task (the task to be accomplished at the worksite) and must not exhaust the cognitive and physiological capabilities of the worker, such as attention for the device, available hands for the device operation, or just willingness to use the device while performing another activity.

Constraints that influence the interaction between the user and the wearable computer system can help to identify the conditions of specific situations and thus describe these in an application-independent and domain-independent way. In focusing on constraints that affect the user interaction with the device, and in mapping these constraints to usability information of user interfaces that were tested with these constraints, we can build up a generic description of the conditions of work situations that help to decide on the applicability of specific interfaces for certain situations.

Before computers were mobile, the interaction was mainly influenced by three components: the computing device, the user and the application that was supported by the computer. Now, we face two more categories that have to be added: the environment in which the device is used and the task that the device supports. Thus, the design of mobile IT support is limited by constraints with respect to the kind of *task* to be performed; the *application*, for which the task is performed; the influences on the execution of the task caused by the *environment*; the *device* chosen as the supporting hardware platform; and the abilities and work patterns of the *user*.

C. Business Process Modeling

Business Process Modeling (BPM) helps to describe and document the activities in a company and thus to share the knowledge about "what's going on" between different groups within and around the company. In recent years, the Unified Modeling Language (UML) became a standard description language for process modeling [2]. The UML defines processes as 'the functions in the business that consume, refine, or use objects to affect or produce other objects' [3]. 'Objects are the "things" in the business; they may be physical, such as people, machines, products, and material, or more abstract, such as debts, instructions, and services'. Business processes can also be seen as the activities performed to serve the customer, directly or indirectly by affecting other processes or objects [4]. In that sense, BPM helps to describe all processes and their interrelation that are involved to reach the business goals of the company.

II. BPM AND WEARABLE COMPUTERS

Wearable computers are the interfaces between humans and the IT infrastructure of a company. They bridge the "last mile" between the computer system and the worker, since they can be worn and thus taken anywhere the worker goes and works. For BPM this means that we can assume the computer system to be available and operatable at any time. In other words, we assume that all activities in which a worker wears a computer system are computer-supported processes.

On the other hand, we have to take a close look at how to design the interaction between the wearable computer system and the user to ensure that in a given work situation the underlying constraints indeed allow for adequate IT support.

Given these two assumptions, we believe that applying BPM for describing the use of wearable computers helps the different groups within a company to better understand the advantages of using wearable computers, e.g., if the controlling department talks to IT services. Furthermore, and this relates back to our work on the *Interaction Constraints Model*, we see the opportunity to describe the constraints for the use of wearable computers in a domain-independent and application-neutral way and to integrate this description onto the Business Process Model. That way, we enable a broader range of people to describe constraints for certain work situations which will then be evaluated by the designer of the wearable computer system.

A. Motivation for BPM and Wearable Computers

While talking to companies about applying wearable computers to support MRO processes, we realize that most of them manage their MRO data using enterprise resource planning (ERP) systems, such as SAP R/3 [5] or PeopleSoft [6]. While developing and testing prototype systems for these companies, we had to talk to various people of different divisions to define and agree on the best way to integrate the mobile IT solution into their ERP system. During this time, we analyzed work processes, defined the structures and interfaces for data exchange, and finally set up the hardware and software concept for the wearable computer system.

In order to standardize these steps and to reuse them for other projects, either within the company or with other companies, we propose to represent this additional information concerning mobile IT usage within a Business Process Model. That way, existing process models can be reused and applied to new business processes. Furthermore, different views on the processes can be provided that allow each project participant to enter and review the parts of the model relevant to his / her role in the project.

B. Approach for Applying BPM and Wearable Computers

After completing several wearable computer projects and developing the *Interaction Constraints Model*, we realized that to apply these research results to real world projects we would either have to develop a commercial product or to transfer the basic ideas to an existing modeling tool. While the first approach would have the advantage of resulting in a specialized tool, the latter approach enables us to more easily reach users and more importantly to provide them access to the functionality of the existing modeling tool.

There are quite a number of modeling tools, mostly computer-aided software engineering (CASE) tools, such as Rational Rose [7], which are targeted to the task of modeling software processes and which support (semi-) automatic generation of software code. Other tools allow for process modeling by providing enriched activity diagrams or simple graphic models, such as Microsoft Visio [8].

C. The ARIS Toolset™

We decided to use ARIS, the Architecture of Integrated Information Systems, by IDS Scheer. The modeling tools ARIS Web Designer™ and ARIS Toolset™ allow for modeling business processes in many different ways and from different views. ARIS offers predefined templates that simplify and standardize modeling certain businesses and even can map to standard ERP systems and describe the related processes. Due to their close relationship to SAP, ARIS offers special interfaces for modeling processes of SAP's ERP software R/3 and is widely used for business process reengineering while rolling out a new ERP system [9].

ARIS was initially developed by August-Wilhelm Scheer at University of Saarland and then commercialized by IDS Scheer. It is based on the ARIS house of Business Engineering, a representation of Scheer's BPM methodology. The idea is to allow for a clear description of complex circumstances separated into the organization, the functionality and the documents of business processes. Together with SAP, IDS Sheer developed the methodology of Event-driven Process Chains (EPC), which combines elements of Petri nets, stochastic networks after Elmaghraby and GERT (Graphical Evaluation and Review Technique) [10]. With EPCs, ARIS offers a simple modelling method to quickly describe business processes. The user can refine these EPCs to include additional related information and transfer the EPCs to different views and representations, showing business processes in different notations and with different (filtered) levels of detail.

The following sections describe a case study in which we illustrate how we use ARIS to describe MRO processes and how we can use BPM combined with the ICM as a design tool for wearable computer systems.

III. CASE STUDY: APPLYING ARIS TO THE INTERACTION CONSTRAINTS MODEL WHILE MODELING MRO PROCESSES

For this case study, we will describe a portion of a project on which we worked with a machine manufacturer that is introducing wearable computers for its MRO processes. This machine manufacturer has hundreds of pieces of machinery and a fleet of several hundred transportation vehicles that need to be maintained. All MRO activities are managed with the SAP R/3-PM module for plant management. This means that a wearable computer system which handles MRO data and supports MRO processes needs to interface with SAP-PM.

Our objective in this project was to change their paper-based data collection processes to computer-supported processes using mobile and wearable computer systems. As part of this project, we modeled the underlying processes with ARIS, including the actual work situations - mostly data collection tasks.

A. Company Overview

In order to categorize the processes for the whole company, and to allocate specific business processes within that company, we used the organizational chart diagram. In that way, we illustrated the overall structure and then refined certain parts of the Business Process Model. Figure 3 shows how plant management was integrated into this machine manufacturing company.

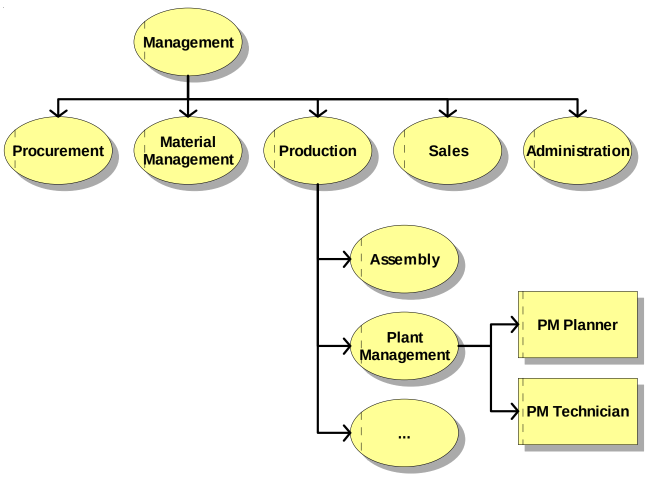

Fig. 3. Organizational chart showing the integration for plant management in the machine manufacturing organization.

Going top-down, we could then continue to model the different plant management processes. ARIS allows for role-based access management. Thus, once this structure is set up, we can give different user groups access rights for specific process models, depending on their position and tasks in the company. A maintenance planner, for example, can have write access to the inspection models, while a maintenance technician might only have read access to review how specific inspections must be performed and a controller needs to have access to the financial data of maintenance processes.

B. MRO Processes

At the next level of detail, we modeled an MRO process, using an extended Event-driven Process Chain (eEPC) diagram. Figure 4 shows an overview of a maintenance process from the moment the maintenance request arrives at the shop to the moment the maintenance is performed and documented.

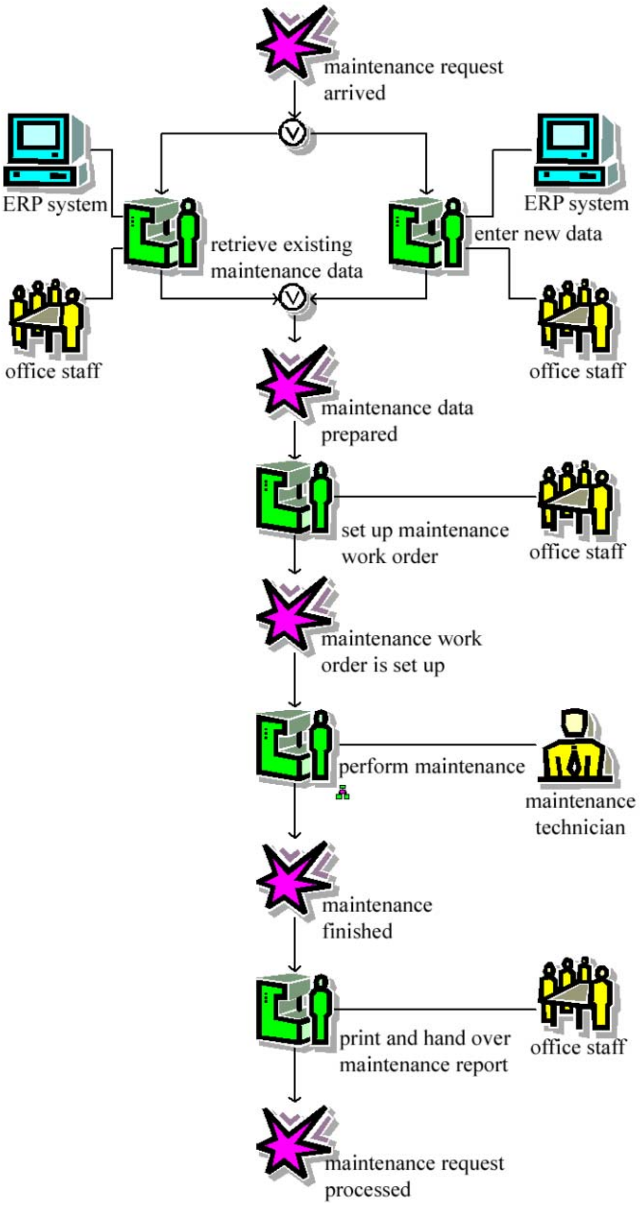

Fig. 4. Industrial process eEPC of a maintenance process.

With the help of this eEPC, one can quickly identify the needed resources and participants of the process. It does not yet define the maintenance method, or the single steps that the maintenance technician will perform, but it offers the links to corresponding, more detailed diagrams.

C. Maintenance Methods

We can differentiate between three basic methods of maintenance: damage-based maintenance, time-based maintenance and condition-based maintenance [11]. Figure 5 shows the damaged-based maintenance business process.

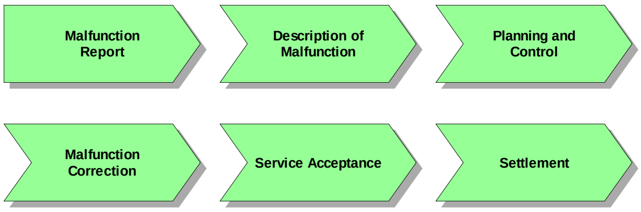

Fig. 5. Damaged-based maintenance in a value-added chain diagram after Stengl [11].

In this project, all three types of maintenance methods exist. Furthermore, due to the fact that the company has to maintain machinery as well as vehicles, the system must support maintenance of both stationary and moving objects. This means that we have to adjust the wearable computer system to support MRO processes with changing conditions. Therefore, we used ARIS in the design phase and reviewed the Business Process Models of the maintenance planners and extended those with the information defined in the *Interaction Constraints Model*.

D. Interaction Constraints Model: A Work Situation in ARIS

In the *Interaction Constraints Model*, we described work situations using the constraints that occur on the interaction between the user – in our example the maintenance technician – and the wearable computer.

"Constraints" are the essential components of the model. They contain the information about the nature of the constraints, such as a visual display not being readable, and the influence from a specific work situation and a specific work activity, which describe the actual cause of the constraint. A constraint can be defined as "a restriction on the degree of freedom we have in providing a solution" [12]. This "solution", in the case of the *Interaction Constraints Model*, represents the applicability of certain user interaction means. We categorize constraints in five constraint categories: *User*, *Environment*, *Task*, *Application*, and *Device*. In mapping the constraints to these categories, the resulting restrictions on the user interface design become more obvious and reproducible. For example, we can map the requirement that a "user shall wear protective gloves" to a constraint stating that a "user's sense of touch is restricted".

In ARIS, we can link those categories together and define the different constraints and their values in the different objects. Figure 6 shows an example how a specific task can be extended to store constraint information. We linked the five objects together, while the object 'task' can be the actual object entity of the maintenance plan of another diagram. Thus, we again used ARIS to link different diagrams and different views together, i.e. the view of the maintenance planner with the view of the designer of the wearable computer system. By doing so, we integrate the mobile IT system design into the Business Process Model of the company.

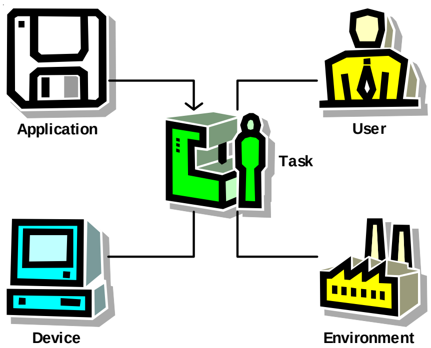

Fig. 6. Work situation modeled in ARIS. Each of the categories stores attributes according to the *Interaction Constraints Model.*

ARIS allows us to store the actual constraint information in "user-defined attributes" of the objects. Thus, we stored constraint attributes in these attribute fields. For example, the environment object contains four attributes, namely *lighting*, *noise*, *cleanliness* and *roughness*, which all can take the values *low*, *normal* or *high*. We intentionally separated the constraint categories into five different objects to be able to re-use these objects for modeling other work situations. That way, we can for example re-use the environment constraints whenever we perform tasks in the same location.

Using this mechanism in ARIS, we could transfer the *Interaction Constraints Model* to a commercially available tool. This enables us to do two things: to integrate design information for wearable computer systems with the companies' process structures; and to provide the base for evaluating this information while designing future systems.

E. Interaction Constrains Evaluation

In order to use the concept of the *Interaction Constraints Model* for aiding the development of wearable computer systems, we have to set up a method to query the information that we previously entered. The goal in originally developing the *Interaction Constraints Evaluation*, as we defined it in our previous work, is to provide support in finding work situations that have the same or at least similar sets of constraints. ARIS offers search functionality that allows for Boolean search on the attributes of objects. Thus, we can define a query that returns a set of objects that contains the same attribute information and thus have the same constraints on a specific work situation.

The main advantage of using ARIS is that we not only get the work situations themselves as results of a query, but also their relationships within the Business Process Model. Figure 7 shows an actual work situation taken from a maintenance task at a shop. The small icon beneath the task object indicates a relationship to other diagrams. Clicking on the icon will open up an eEPC that describes the maintenance activity in more detail – a step-by-step description that is available for PM technicians.

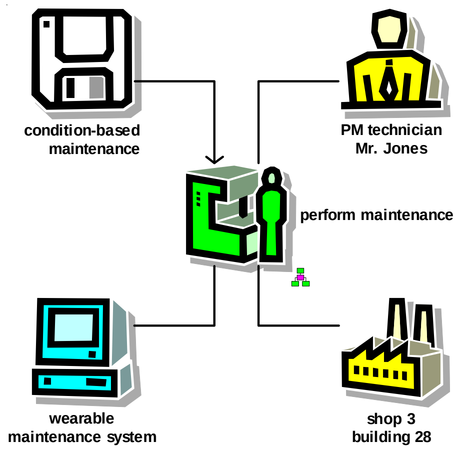

Fig. 7. An actual work situation linking to a task 'perform maintenance'. The icon beneath the task indicates further relationships to other diagrams.

The different connected objects contain the constraint information about *Application* (condition-based maintenance), *User* (PM technician), *Task* (perform maintenance), *Device* (wearable maintenance system) and *Environment* (shop 3, building 28). Figure 8 shows the attribute table which contains the constraint information for the *Environment* object.

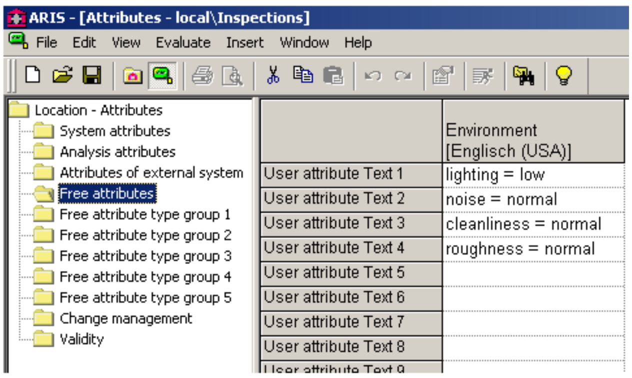

Fig. 8. Table in ARIS, showing the constraint information of an *Environment* object.

Exploring the relationships of the object 'perform maintenance' opens up a diagram as shown in Figure 9, which lists all relationships in the database defined for this object. Thus, we can quickly navigate through the object hierarchy to get an overview on how the object is integrated into the Business Model.

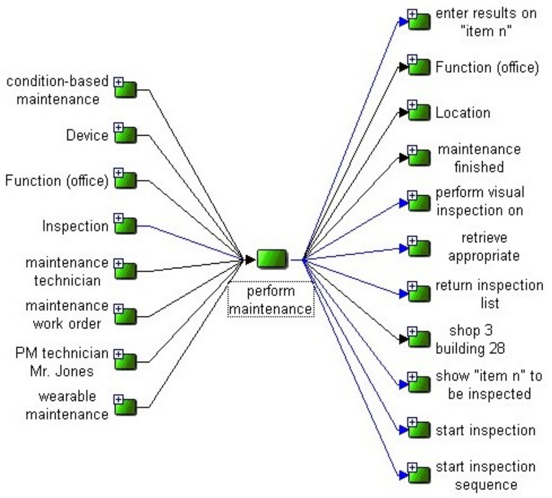

Fig. 9. Relationships of task 'perform maintenance'.

The functionality provided by ARIS goes beyond the evaluation capabilities of our first proof-of-concept implementation of *ICE Tool* (Interaction Constraints Evaluation Tool [13]). Thus, we see great potential to define new and additional evaluation criteria while using a commercial modeling tool. This case study shows that integrating the design of a mobile or wearable computer system in the Business Process Model of a company is a viable approach that we will continue to explore, evaluate, and refine.

IV. Conclusion & Outlook

In this case study, we modeled and evaluated a real-world maintenance project with a manufacturing company using a combination of BPM and ICM. In doing so, we determined the applicability of using the ICM within a commercial Business Process Modeling tool to provide more detail about the business processes needed when designing mobile computing support systems. We see ARIS as a viable tool to incorporate the ICM and to use the method to assist the design of wearable computer systems. We used Business Process Modeling as an integrated approach to account for other business processes during the design phase and to document all relevant information during the design. As a result, ARIS incorporates a better case base that provides examples for future system designs. It can provide not only previously entered design information, but as well give access to the models of supported and related business processes. That way, it will be easier to overview the context of previously designed systems.

In future steps of this research, we will investigate the possibility of integrating the concepts of the *Interaction Constraints Model* more deeply into ARIS by defining appropriate objects and queries; we will use the system to assist and document real-world design phases using this method; and we will apply the system to different domains, such as plant management, construction projects or medical practices to rethink and reengineer the processes that can be supported by wearable computers.

V. REFERENCES

[1] C. Bürgy and J. H. Garrett, Jr, "Research and Industry: An Overview of Speech Interaction with Wearable Computers in Industrial Applications," *Proceedings of the 1st International Forum on Applied Wearable Computing (IFAWC)*, 2004.

[2] G. Booch, Grady, J. Rumbaugh and I. Jacobson, "The Unified Modeling Language User Guide," *Addison Wesley Longman Inc*, 1998, pp.13-16.

[3] M. Penker, H.-E. Eriksson, "Business Modeling With UML: Business Patterns at Work," *Wiley; 1 edition*, 2000, p. 4.

[4] I. Jacobson, M. Ericsson and A. Jacobson, "The Object Advantage: Business Process Reengineering with Object Technology," *Addison-Wesley*, 1995.

[5] M. Doane, "SAP Blue Book, A Concise Business Guide to the World of SAP," *Good Life Publications, 1st edition*, 1998.

[6] L. Anderson, "Understanding PeopleSoft 8," *Cap Gemini Ernst LLC, Young U.S Sybex Books, 1st edition*, 2001.

[7] W. Boggs and M. Boggs, "Mastering UML with Rational Rose 2002," *Sybex Books*, 2002.

[8] M. H. Walker, N. J. Eaton and N. Eaton, "Microsoft Office Visio 2003 Inside Out," *Microsoft Press*, 2003.

[9] IDS Scheer, "ARIS Design Platform – Broad Solution Spectrum for Business Process Management," *White Paper 2004*, (www.ids-scheer.com, retrieved June 30th 2004), pp. 4-6.

[10] A.-W. Scheer, F. Abolhassan, W. Jost and M. Kirchmer, "Business Process Excellence – ARIS in Practice," *Springer*, 2002, pp. 5.

[11] B. Stengl and R. Ematinger, "SAP R/3 Plant Maintenance – Making it work for business," *Pearson Education Limited*, 2001, p. 19.

[12] D. Leffingwell and D. Widrig, "Managing Software Requirements – A Unified Approach," *Addison-Wesley*, 2000, p. 44.

[13] C. Bürgy, "An Interaction Constraints Model for Mobile and Wearable Computer-Aided Engineering Systems in Industrial Applications," *Thesis, Dept. of Civil and Environmental Engineering, Carnegie Mellon University, Pittsburgh, PA, USA*, 2002, pp. 76-81.