PHYSICAL-VIRTUAL CONNECTION IN UBIQUITOUS BUSINESS PROCESSES*

Pau Giner, Manoli Albert and Vicente Pelechano
Department of Information Systems and Computation, Technical University of Valencia
46022 Valencia, Spain

Keywords: Ubiquitous Computing, Business Process, Model Driven Engineering.

Abstract: Ubiquitous Computing (Ubicomp) when applied to organizations can improve their Business Processes. An example of improvement is the integration of real world objects in the Information System. This reduces inconsistencies in the information and improves information acquisition rates. Automatic identification is the key technology to achieve this paradigm shift. The present work inspects the relevance of the identification concept for Business Processes supported by Ubicomp technologies and presents a conceptual framework to define the elements involved in the identification process. Taking into account that Business Processes tend to be very dynamic, it is important to have technological-independent definitions in order to enable the evolution of systems. The presented framework is independent of the underlying technology, in order not to be locked with one particular solution.

1 INTRODUCTION

Business Processes in organizations usually involve real-world objects. Information Systems need mechanisms to connect those elements at the physical space with the information about them at the digital space. Maintaining the connection between both in sync is essential. Baggage loss is a common problem in aviation industry that illustrates the consequences of breaking this linkage. During 2006 the Association of European Airlines reported that they had mishandled more than five million bags (AEA, 2006). Concerned with this problem, International Air Transport Association is considering the usage of Radio Frequency ID (RFID) technology[1] to improve logistics.

Ubiquitous Computing (Ubicomp) technologies such as automatic identification (Auto-ID), localization, sensor and wireless connectivity can help to bridge physical and digital spaces. Ubicomp represents a computation paradigm where services are seamlessly integrated into the environment and accessed in a natural way.

Ubiquitous Business Processes (UBPs) result from the application of Ubicomp to support Business Processes in organizations. The introduction of Ubicomp in organizations is promising and numerous benefits have been detected in economic terms (Langheinrich, 2002), and process improvement terms (Fleisch, 2001), (Sandner 2005), (Strassner, 2002).

In UBPs, real world elements participating in the process turn into intelligent interconnected objects and the information flow between the real world and the Information System gets automated. Without the need for humans to act as information carriers, information could be acquired automatically, with more precision and at higher rates.

Identification of real-world objects is the prerequisite for "smart" behavior (Römer, 2004). Therefore, Auto-ID is considered the core element for the Ubicomp enablement of systems. Auto-ID acts as a foundation for other technologies such as localization and moreover it represents the automation in the linkage between real world objects and their computational counterparts at the Information System. This linkage constitutes the process of identification and it is the central subject of interest for the present work.

Different technologies can be applied to implement Auto-ID mechanisms. Due to the dynamic nature of Business Processes, the change in

*This work has been developed with the support of MEC under the project SESAMO TIN2007-62894 and cofinanced by FEDER.

[1]http://www.iata.org/stbsupportportal/rfid/

Giner P., Albert M. and Pelechano V. (2008).
PHYSICAL-VIRTUAL CONNECTION IN UBIQUITOUS BUSINESS PROCESSES.
In *Proceedings of the Tenth International Conference on Enterprise Information Systems - ISAS*, pages 266-271
DOI: 10.5220/0001697102660271

requirements can have a technological impact in the system, and the introduction –or replacement– of a particular technology should not suppose a burden to the evolution of the system. Defining the identification process in an abstract way favours this evolution, since the concepts defined become independent of the technology used for their implementation.

This paper is concerned with the development of appropriate identification modelling concepts for UBPs to treat automated and non-automated identification in a homogeneous manner. The contribution of this work is a conceptual framework to reason about identification independently of the underlying technology. In this way concepts common to any identification technology are defined, so the Information System can migrate seamlessly from one technology to another.

The remainder of the paper is structured as follows. Section 2 presents the conceptual framework and the theoretical background in which it relies. Section 3 defines the functionality and components an Information system should offer to support the presented framework. In Section 4, some insights are given about a prototype implementation to verify the applicability of the framework. Section 5 presents related work. Finally, Section 6 presents some conclusions and further work.

2 THE IDENTIFICATION CONCEPT

Identification implies to cover the gap between real world elements and the information about them in the Information System. Auto-ID is a particular kind of identification process where technology is used to automate certain operations. Different technologies such as barcodes, infrared beacons or RFID tags offer identification capabilities at different levels of automation. Identification process can even be completely manual, as it occurs in most Information Systems nowadays. Human users are in charge of identifying the real world elements and transmit this information to the Information System.

Whatever physical method is used to store and communicate the identity of an element, this information should follow a certain codification. Numbering schemas such as Universal Product Code (UPC) or Electronic Product Code (EPC) are commonly used in the consuming goods industry and define the formats that a product identifier could follow.

In the following sections, elements involved in the identification process will be described. In order to abstract technical details and formalize their definition, concepts from the modeling area are used.

2.1 Theoretical Basis

Our characterization of the identification idea is based on the precise definition of the model concept and how it is related to systems. The concept of model is defined by Bézivin as *"a simplification of a system built with an intended goal in mind. The model should be able to answer questions in place of the actual system"* (Bézivin, 2001). Following the previous definition, an Information System can be considered a model as it is a computable simplification of a system under study used for answering questions about it.

Favre establishes a basic taxonomy for systems and some relation kinds among them (Favre, 2004). Systems are classified as *Physical Systems* –observable elements or phenomenons pertaining to the physical world–, *Digital Systems* –residing in computer memories and processed by computers– and *Abstract Systems* –ideas and concepts that eventually reside in human mind to be processed by human brains–.

The most relevant relation between systems is the *RepresentationOf* relation, noted as μ. This relation establishes two roles between systems, one system is considered the *system under study* and the opposite acts as a *model*. Thus no system is a model *per se*, being a model is a role played by a system in relation to another system.

The concept of set and two additional relationships are also introduced by Favre. The *Set*, as defined by the set theory, is considered in the framework as a kind of Abstract System. The *ElementOf* (ε) relation is used to express the inclusion of a system in a set. The *ConformsTo* (χ) relationship is a derived relation expressing the concept of metamodel as "a model of a modelling language".

These relationships presented are used to define the concepts involved in the identification process. The conceptual framework that includes these concepts is presented below.

2.2 A Conceptual Framework for Identification

The concepts involved in the identification framework are depicted in Figure 1. The framework defines concepts at physical, digital and abstract spaces. An *Element* is part of the *Physical Space*. It represents any real-world object such as a bottle in a supermarket or a package in a warehouse. The Information System can contain information about an element such as its price or its manufacturer. This *information* is a representation of the current element at the *Digital Space*. The information in the system can be considered a projection of the physical element in the digital space as only relevant characteristics are present in the Information System. An *Identifier* is a representation of both the element and its digital counterpart. The *Identifier* is a member of a likely infinite set of identifiers constituting a language, a model of which is a *Codification* (the Identifier is then, conformant to this codification).

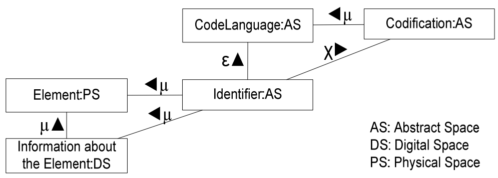

Figure 1: Conceptual framework for identification.

The common scenario is to move from the physical space to the digital space. Identifier retrieval can be done using a barcode reader, an RFID antenna or by typing the element code by hand. Information in the system should be searchable using this identifier. And the codification used to encode the identifier should be known.

However, the identification process involves several transitions in both directions thru the presented relationships. Thus the relationships defined in the framework are bidirectional to allow other scenarios. For example, prior to detection, identifiers should be transferred to the physical world.

In addition, there are no restrictions of cardinality in the relationships presented in the framework. An element, for example, can have multiple identifiers. In the example, a human-readable code (a sequence of digits printed on the bottle label) can complement the barcode-based identifier. Using multiple physical representations of an identifier can help to maintain the identification process in case of degradation of the physical supports.

A more detailed analysis of the needed operations that an Information System should offer to cover the indicated transitions is presented in the following section.

3 IMPLICATIONS FOR THE INFORMATION SYSTEM

When the presented framework is applied to define the identification mechanisms of an Information System, the architecture of the identification system should be defined. This section detects the operations needed, which software elements should be defined to support the framework in a modular way and some requirements that should be fulfilled by the Information System regarding the identification process.

According to Kindberg, an identification-resolution system is composed by five essential tasks:

“Identifiers are *minted*, *captured* and *converted*; and they are *bound* to resources. Bindings are created and looked up. *Resolution* is the process of looking up bindings from identifiers and returning the bindings or the resources to which they refer.” (Kindberg, 2002).

These tasks are consistent with the conceptual framework we have previously defined. Each task can be seen as a transition through the relations defined in the framework, as depicted in Figure 2. ID creation has been defined in two different steps, the generation of the identifier following a certain codification and the assignment to the physical object (or *minting*); Identifiers can be obtained by *capturing* them from the physical element or by *identifying* a piece of information. *Binding* supposes the creation of an association between Identifiers and information in the system. The *conversion* of identifiers produces a new identifier of a different codification.

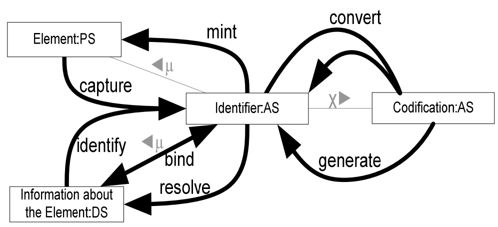

Figure 2: Identification tasks.

In order to keep physical and digital spaces connected, mechanisms supporting these tasks should be defined. Information Systems should provide means to support them either manual or automatically. Which components should be considered in the design of an identification system in conformance with the presented framework and some remarks about their integration are given below.

3.1 Architectural Components

The presented elements and tasks forming the conceptual framework involve different spaces. However, the Information System is only present at digital space. Therefore some components at digital space should provide the connection to physical space, and some others should represent concepts of abstract space. In order to support the defined tasks in a modular way, the components defined to cover each of these tasks are the following:

- *Minters*, elements capable of obtaining a physical representation of an identifier such as a barcode printer.
- *Capturers*, elements capable of obtaining an identifier from the physical space. Barcode readers, or RFID receivers, are some examples.
- *Codifications*, elements capable of producing new identifiers in a computable form. They contain the information limitations that the identifier has such as a range of allowed values.
- *Mediums*, possible representations that a codification can have. A barcode-based codification can be represented by a barcode or by a sequence of printed numbers. Barcode readers are able to read the former while humans are capable of reading the later.
- *Transformations*: define directional transformations between two codifications.
- *Information Registry*: it is in charge of the binding and information retrieval tasks.

3.2 Information System Requirements

In order to integrate the defined components and support the identification process, the Information System has to satisfy several requirements detailed below.

3.2.1 Manage Codification Dependencies

Not every *minter* can be used to produce any codification for any medium. There is also no universal receiver capable of reading any identifier.

The limitation in the number of codifications a mint, resolution or conversion system can handle should be managed. The software component representing any of those elements should contain metadata indicating the supported codifications and mediums.

Information System should allow the usage of the elements that support a certain codification or have a sequence of transformations to obtain this codification.

3.2.2 Allow Complex Information Retrieval

The relation between physical elements and their virtual counterpart is not always one to one. Physical elements can share the same identifier or contain multiple identifiers.

In supply stores, being impossible to tag the product type (as it is an abstract concept), all its members are tagged instead to represent it to retrieve information such as prize which is not assigned in an individual basis.

The opposite situation is also common. People for example can be identified using email addresses, fingerprints or organization specific identity card numbers. Therefore, *information registry* should support the possibility of having multiple identifiers, and multiple information pieces per identifier when information is resolved or binded.

3.2.3 Offer User-Valuable Operations

In addition to provide the basic mechanisms for covering the essential identification tasks, more complex operations –resulting from the composition of the basic ones– should be considered.

Since physical elements are subjected to degradation, Information Systems should offer mechanisms to offer common sequences of operations. In this way users can perform –or program– maintenance tasks easily.

Identification regeneration is an example. Identification regeneration consists in identifying a piece of information and minting the identifier it has.

4 IMPLEMENTATION DETAILS

A prototype implementation was developed to prove that the presented framework is expressive enough to deal with different identification technologies. For the development, RFID, fiducials, and manual identification where chosen as identification technologies.

The software elements supporting the different identification tasks were componentized to promote reusability. In this way, codifications can be used independently of the underlying technology, as far as the types supported by the technology form a superset of the required for that codification. For example, Serial Shipping Container Code (SSCC) is a eighteen digit codification that can be used in EPC-based RFID systems as well as in barcodes. However, the standard fiducial set contains only 90 symbols, so it cannot support this codification.

Web Services technology has been chosen to form the architecture of the system as it is transport independent and enables the definition of distributed systems following a Service Oriented Architecture. This allows the integration of identification systems from different vendors.

The fiducial based identification subsystem is based on reacTIVision[2]. Fiducials –specially designed markers recognizable in a real time video stream– are used to identify elements (Bencina, 2005).

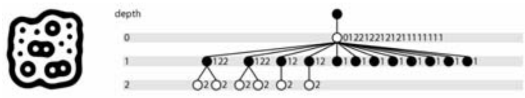

Figure 3: A fiducial and its left heavy depth sequence (Bencina, 2005).

The usage of fiducials results in an intuitive and affordable identification solution. The complete Auto-ID system is composed by a USB video camera as a *capturer*, a common printer as a *minter* and the reacTIVision framework to handle the encoding and decoding tasks. The *codification* consists in a module that generates numerical values from 0 to 90. The printer supports two *mediums* for this codification, one corresponding to the fiducial image corresponding to the code in the standard fiducial set, and another just by printing the number. These components of the infrastructure have been correspondingly wrapped in order to be accessed as Web Services.

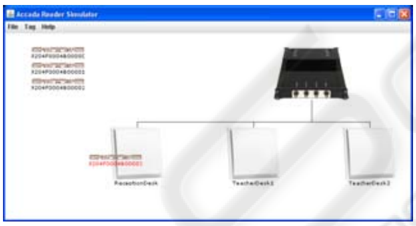

Figure 4: Accada Reader Simulator.

Identification subsystem supporting RFID is based on Accada[3], an open source RFID prototyping platform. The Accada platform deals with readers, filters and RFID data aggregation following EPCglobal standards, the predominant standardization effort of the RFID community. The usage of such middleware eases the development and reduces the technological heterogeneity. In Figure 4 the simulation tool used to validate the case study is shown.

[2]http://www.iua.upf.es/mtg/reacTable/?software

[3]http://www.accada.org

Web services are also used as a wrapper for the user interaction when acting as an identification system. In this last scenario a web application was used to allow the user to introduce a numeric code and to obtain system information.

5 RELATED WORK

The idea of automating the linkage between real and virtual elements is nothing new. Research has considered the application of printed markers (Ishii, 1997), (Ljungstrand, 2000), (Rekimoto, 1995), RFID technology (Floerkemeier, 2005), (Römer, 2004), (Want, 1999) or infrared beacons (Kindberg et al., 2002) as a way to enforce this linkage.

Some frameworks for the development of Ubicomp applications such as One.world (Grimm, 2002), Interactive Workspaces (Johanson, 2002), Cooltown (Kindberg et al., 2000) or Gaia OS (Roman, 2002) have been developed to abstract this technological heterogeneity. Auto-ID specific middleware has been also developed such as Accada, SAP's Auto-ID infrastructure (Bornhövd, 2004), Java RFID Api (Sun 2006) or OAT C4 Architecture (OATSystems 2006). These infrastructures provide useful programming primitives to filter and aggregate information from Auto-ID devices and transmit application-relevant events. The APIs provided by these frameworks supply relevant information at application level allowing developers to build their systems on top on them.

Providing constructs to represent the needed mechanisms in a technological agnostic way is what this work tries to address, so these infrastructure elements are complementary to the objectives of the present work.

6 CONCLUSIONS

The present work introduces a conceptual framework to define in a precise way the elements involved in the identification process and the relationships among them. This is useful to determine the operations and components that an Information System supporting identification should provide independently of the used technology.

In the present work the identifier is not considered to have a meaning. In some numeric schemas, it has several parts to indicate company, location reference and other information and the like. With the present implementation, the elements in charge of codification should format the identifier correctly.

How these elements are linked with the specific information constitutes further work.

The capabilities to store information that technologies such as RFID have, has not been considered in the present work. Considering the possibility of distributed information across different Information systems – or storing devices such as the RFID tag– requires the definition of mechanisms to maintain information consistency.

REFERENCES

Association of European Airlines (AEA) (2006) Consumer report.

Bencina, R.; Kaltenbrunner, M.; Jorda, S. (2005), Improved Topological Fiducial Tracking in the reacTIVision System, Computer Vision and Pattern Recognition, 2005 IEEE Computer Society Conference on , vol.3, pp. 99-99, 20-26.

Bézivin, J., Gerbé, O. (2001), Towards a Precise Definition of the OMG/MDA Framework. In: Proceedings of ASE’01

Bornhövd, C., Lin, T., Haller, S., Schaper, J. (2004), Integrating Automatic Data Acquisition with Business Processes - Experiences with SAP’s Auto-ID Infrastructure. In Proceedings of the 30st international conference on very large data bases (VLDB), pages 1182–1188, Toronto, Canada.

Favre, J.M. (2004), Foundations of Model (driven) (Reverse) Engineering: Models - Episode I: Stories of the Fidus Papyrus and of the Solarus. In: post-proceedings of Dagsthul Seminar on Model Driven Reverse Engineering.

Fleisch, E. (2001). Bussiness Perspectives on Ubiquitous Computing. M-Lab Working Paper No. 4. University of St. Gallen, Switzerland, 2001.

Floerkemeier C., Lampe, M. (2005), RFID middleware design – addressing application requirements and RFID constraints. In Proceedings of SOC’2005, pages 219–224, Grenoble, France.

Grimm, R., (2002), System support for pervasive applications, Ph.D. Thesis, University of Washington, Department of Computer Science and Engineering.

Ishii, H., Ullmer, B. (1997), Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms. In: CHI ’97: Proc. of the SIGCHI conference on Human factors in computing systems, ACM Press 234–241

Johanson, B., Fox, A., Winograd, T., (2002), The interactive workspaces project: Experiences with ubiquitous computing rooms, IEEE Pervasive Computing 1(2) 71–78.

Kindberg, T. (2002), Implementing physical hyperlinks using ubiquitous identifier resolution, in 'WWW '02: Proceedings of the 11th international conference on World Wide Web', ACM Press, New York, NY, USA, pp. 191—199

Kindberg, T., Barton, J., Morgan, J., Becker, G., Caswell, D., Debaty, P., Gopal, G., Frid, M., Krishnan, V., Morris, H., Schettino, J., Serra, B., Spasojevic, M. (2000), People, Places, Things: Web Presence for the Real World. Mob. Netw. Appl. 7(5) (2002) 365–376

Langheinrich, M., Coroama, V., Bohn, J., Rohs, M. (2002), As we may live - Real world implications of ubiquitous computing. Technical Report, Institute of Information Systems, Swiss Federal Institute of Technology, Zurich, Switzerland.

Ljungstrand, P., Redström, J., Holmquist, L.E. (2000), WebStickers: Using Physical Tokens to Access, Manage and Share Bookmarks to the Web. In: Proc. of DARE 2000 on Designing augmented reality environments, ACM Press 23–31

OATsystems (2006). OAT C4 Architecture.

Rekimoto, J., Nagao, K. (1995): The World through the Computer: Computer Augmented Interaction with Real World Environments. In: UIST ’95: Proc. of the 8th annual ACM symposium on User interface and software technology, ACM Press 29–36

Roman, M., Hess, C., Campbell, R. (2002), Gaia: An OO middleware infrastructure for ubiquitous computing environments. In: ECOOP Workshop on Object-Orientation and Operating Systems (ECOOP-OOOSWS). Malaga, Spain.

Römer, K., Schoch, T., Mattern, F., Dübendorfer, T. (2004): Smart Identification Frameworks for Ubiquitous Computing Applications. Wireless Networks 10(6) 689–700.

Sandner, U., Leimeister, J. M., Krcmar, H. (2005), Business Potentials of Ubiquitous Computing. In: *Proceedings of the Falk Symposium*. No. 146 Gut-Liver Interactions: Basic and Clinical Concepts. Innsbruck, Austria.

Strassner, M., Schoch, T. (2002), Today’s Impact of Ubiquitous Computing on Business Processes. In: Pervasice Computing. First Int. Conf. Pervasive Computing 2002, Zurich, Switzerland.

Sun Microsystems (2006). Java System RFID Software 3.0 Developer Guide. www.sun.com.

Want, R., Fishkin, K. P., Gujar, A., Harrison, B.L. (1999), Bridging Physical and Virtual Worlds with Electronic Tags. In: CHI ’99: Proc. of the SIGCHI conference on Human Factors in Computing Systems, Pittsburgh, PA, USA 370–377