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On the Management Implications of Ubiquitous Computing: An IS Perspective

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Abstract

This paper describes the development and implications of Ubiquitous Computing from an IS perspective. With the advent of Radio Frequency Identification (RFID) and similar technologies, information systems get the capability of collecting data from the real world in real-time at a fraction of the cost of traditional manual data entry. This enables the cost-effective capture of considerably more finely grained data on the one hand and significantly more differentiated management control loops on the other. As a consequence, this development will lead to faster, more reliable and more efficient processes as well as to 'smart' products and services.

Keywords: Ubiquitous Computing, RFID, Sensors

1 INTRODUCTION

As a discipline, Ubiquitous Computing (UC) has become progressively more visible over the past years. Evidence of this trend is to be found in newly established journals (e.g. IEEE Pervasive Computing), conferences (e.g. UbiComp or Pervasive), and research programs in which researchers from the fields of distributed systems, human-computer interfaces, sensor technology, etc. and increasingly from information systems exchange and benchmark their ideas.

While not so many years ago, the idea of smart physical objects smacked of science fiction, individual UC technologies have today reached a level of maturity which allows for the development of productive business applications. In the area of radio frequency identification (RFID), for instance, standardisation is already well advanced and several large companies have begun to implement the technology in order to track the flow of physical items in their logistics processes. At the same time the social and political discussion of UC-related risk issues, e.g. privacy and health, has begun. Both developments are indications that the technology has gained a foothold in business.

Most applications-oriented UC research that has been published in recent years continues to describe consumer-centric scenarios. Examples here are the smart toaster which grills the latest weather report onto the bread, the intelligent milk bottle which tells the refrigerator that it will soon be empty or has passed its expiry date, and the smart doll which will simultaneously become smoke detector and language teacher for the next generation of children. However, the results of initial work carried out in the area of information management echo the findings in e-Business which lead us to believe that the great commercial potentials of UC rather lie in the area of 'business-to-business' (B2B) scenarios.

Against this background, this paper analyses and discusses the relevance and the potentials of UC to information systems research and their practical use in the firm. Our objective is (i) to explore the novelty of UC from an IS perspective in comparison to classic computing paradigms and (ii) to identify its implications for both, IS management practice and research. For this purpose, the paper is divided into the following sections: First, we provide a short overview of the basic concepts of UC and its potential in the context of business applications. Second, we consider UC from different IS-related perspectives in order to get a better understanding of its impact on information management. Third, we discuss consequences of UC for processes, products, and services by means of a few practical examples. The paper closes with an outlook and proposals for further research.

2 BACKGROUND AND MOTIVATION

UC denotes the vision of a future world of 'smart objects', i.e. physical items whose physical shape and function is being extended by digital components. The increasing miniaturisation of computer technology might result in processors and tiny sensors being integrated into more and more everyday objects, leading to the disappearance of traditional PC input and output media such as keyboards, mice, and screens. Instead, people will communicate directly with their clothes, watches, pens, or furniture – and they will communicate with each other and with other people's objects (Ferguson 2002). RFID represents the first instance of a basic UC technology which is poised for mass use. The ability of an object to store a unique identification and report it to its environment constitutes the first step toward the integration of object and information, and provides the basis on which farther-reaching functionality can be built (Want 2004).

More than 15 years ago, Mark Weiser, a researcher at the Xerox PARC, foresaw this development, and described it in his influential article 'The Computer for the 21st Century' (Weiser 1991). Weiser coined the term 'Ubiquitous Computing', referring to omnipresent computers that serve people in their everyday lives at home and work, functioning invisibly and unobtrusively in the background with the aim of supporting them in their work and activities, and to a large extent freeing them from tedious routine tasks. Whereas his ideas sounded rather utopian at the time, today the large-scale use of tiny computerised devices in everyday life seems realistic. The dramatic progress in the miniaturisation of computer components and a continuous fall in prices due to new production techniques and technological developments enable a multitude of new application scenarios (Bohn et al. 2003).

It is neither a single technology nor a specific functionality which is behind UC but rather a bundle of functions which together allow for the creation of a new quality of computing. UC-related research is characterised by a multidisciplinary approach that includes aspects of electrical engineering, computer science, psychology and many more (Satyanarayanan 2002). For this reason, the following list of smart objects' functionalities can be regarded as typical but does not claim completeness:

- **Identification.** Smart objects can be uniquely identified, e.g. by means of a numbering scheme. This identification allows the object to be linked with services and information on the object which is stored on a remote server in the network.
- **Memory.** The object has storage capacity so that it can carry information on its past or future, e.g. a product that records its manufacturing process.
- **Processing logic.** Smart objects may be able to make decisions automatically without a central planning instance, e.g. in the sense of an industrial container which determines its own route through the supply chain.
- **Networking.** In contrast with the simple pocket calculator, smart objects have the capability to connect with resources in a network or even amongst themselves (referred to as 'ad-hoc networking') for the reciprocal use of data and services.
- **Sensor technology.** The object collects information about its environment (temperature, light conditions, other objects, etc.), records it and/or reacts to it (referred to as 'context awareness').
- **User interface.** With the merging of computer and physical object come new requirements to be met by the user interface. This calls for new approaches similar to the mouse & desktop metaphor of graphical user interfaces, e.g. in the form of haptic interfaces.
- **Positioning & tracking.** Smart objects know their location (Positioning) or can be located by others (Tracking), for example at the global level by GPS or inside buildings by ultrasound.

As a consequence, UC creates a direct linkage between physical items and their 'virtual counterpart' (Langheinrich et al. 2000) in the IS, thus enabling automatic collection of a variety of object-related data as well as delegation of decisions from the system to the single object.

3 UBIQUITOUS COMPUTING FROM AN IS PERSPECTIVE

Over the last four decades, the use of information technology in firms has made a major contribution toward the speed, efficiency and accuracy of intraorganisational and interorganisational processes. However, to date it has only been able to provide very limited solutions to a series of entrepreneurial problems related to the visibility and management of physical processes, e.g. shrinkage along the entire supply chain, inventory inaccuracy, grey markets and product counterfeits. The common denominator in all these problems is the persisting lack of integration between the real, physical world or the reality of molecules on the one hand, and the digital world of information systems, the internet or the reality of data and bits on the other hand.

Against this background, the following sections highlight the importance of UC to the field of information systems from various perspectives. In the first section, we argue that UC can be regarded as a next step in the evolution of information systems. The second section describes the close link between the real and the virtual world with the aid of sensors and actuators. The result is a closed digital management control loop as described in section three which enables fully automated process transparency and control for the first time. A further consequence of integrating the real and the virtual world is the cheap availability of data on the status of the real world which enables new business processes and business models.

3.1 Historical view: The evolution of information management

With the development of corporate information management over the last decades, the scope of integration has been constantly expanded (Fleisch and Österle 2000). Here, 'integration scope' describes the number of tasks which an enterprise or enterprise network performs in an information system. The following phases can be distinguished in this evolutionary process (cf. Figure 1):

- **Phase 1.** In the initial stages of electronic data processing, the aim of informatising isolated functions was to automate individual business functions such as e.g. billing. Here, manual operations are transferred to the computer but remain unchanged. This results in isolated solutions, i.e. separate information systems which efficiently support individual operations.
- **Phase 2.** By informatising some of the most important function areas such as e.g. production or financial accounting, integration was achieved and thus the efficiency of entire departments improved. IT enabled the application of new methods for the first time such as e.g. production and financial planning, through which business processes could be redesigned.
- **Phase 3.** The development of Enterprise Resource Planning (ERP) systems offered enterprises the possibility of introducing integrated processes across departments and/or across functions. This meant that consistent processes could be set up from the customer (e.g. sales, order entry) and to the customer (e.g. distribution, billing, payment receipt).
- **Phase 4.** In parallel with the introduction of ERP systems some enterprises began creating closer networks with their customers or suppliers. In a first step, they started employing systems for electronic data interchange (EDI) in order to process mass transactions efficiently.
- **Phase 5.** Today, novel information systems for supply chain management and e-commerce place the customer's processes at the forefront of process and IS design by enabling the integration of interorganisational processes and/or systems and thus a step toward the extended enterprise.

From this historical perspective on the evolution of integrated information systems, UC suggests a new quality of integration which is no longer limited to the information flows of the digital world but also directly links processes in the physical world as well as the associated products (e.g. drugs, textiles) and means of production (e.g. pallets, machines). Thus, the scope of integration crosses the boundaries of information systems and pervades the world of physical goods and processes.

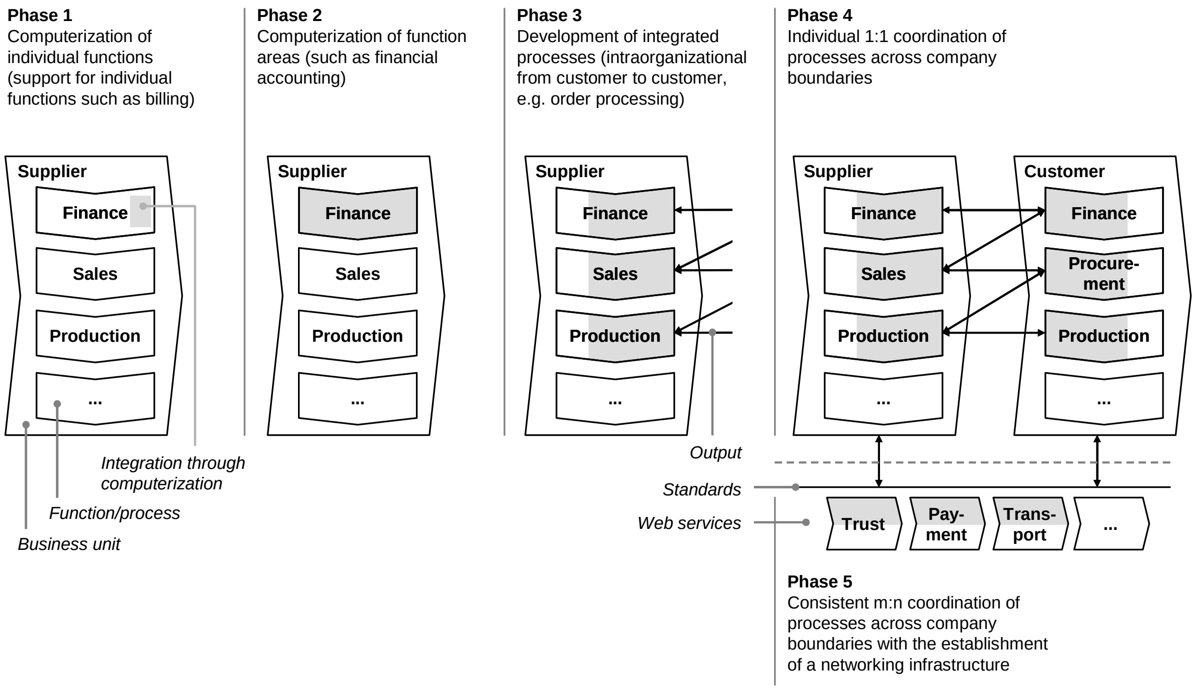

Figure 1: Expanding IS integration from isolated functions to interorganisational networks

3.2 Technical view: The integration of reality

Up to now, IS research and practice have concentrated primarily on the networking of businesses, processes, information systems and humans. They pursue the goal of eliminating ever more so-called ‘media breaks’ as the scope of integration grows, e.g. the multiple registration of an order in different business information systems within a value chain. A media break is comparable to a missing link in a digital information chain and is a contributory factor to the slow speed, intransparency, error susceptibility, etc. of business processes.

UC technologies have the potential to prevent the media break between physical processes and the associated information processing. They enable a fully automatable machine-to-machine relationship between real items and information systems by equipping the former with digital components. They help to reduce the costs of depicting physical resources and operations in information systems by assuming the role of mediator between the real and the virtual world (cf. Figure 2). A descriptive example is an industrial container that knows its position and contents and transfers this information automatically to the inventory management system of a distribution center on arrival at the docking door.

Physical resources can thus communicate with internal and external computer networks without human intervention, e.g. in order to report product identification, location or temperature. While integrated information systems and e-business systems aim to link an ever greater number of applications and databases, UC sets out to integrate these applications and databases with the real operational environment such as the warehouse. Sensor technology (and actuator technology) enables UC-based systems to sense (and/or initiate) changes in state in the real world automatically (Abowd et al. 2002). They make their decisions on the basis of fact-based real-time data from reality and not on the basis of updated accounting values from information systems. In many application scenarios in which decisions are still being made on the basis of statistics or extrapolations today, UC can thus lead to better process management.

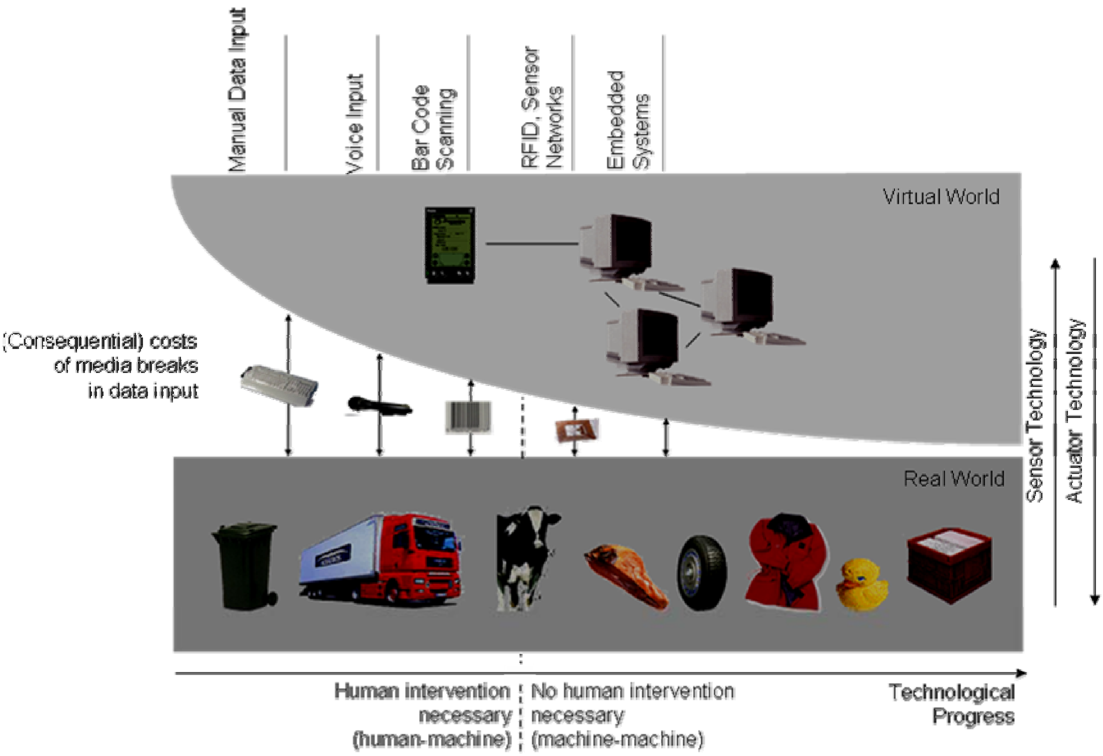

Figure 2: Integration of the Real and the Virtual World

3.3 Process view: Digitisation of the management control loop

From a high-level perspective, the execution and management of business processes can be regarded as a control loop that comprises a 'point of creation' (POC) and a 'point of action' (POA). In the best case, information instantaneously becomes available at the POA as and when it arises at the POC, thus allowing for immediate reactions to business events. In reality, both POC and POA could be part of different organisational units and therefore necessitate intraorganisational and interorganisational information flows. The POC, for example, could be a retailer's check-out, the respective POAs being alongside the scanner check-out the internal retailing and logistics system as well as the collaborative procurement and forecasting system which links the retailer to his supplier.

As can be seen from this example of the retail trade, a large number of POCs and POAs can be identified in the supply chain – always at the precise moment when information is created or used. The choice of POCs and POAs will depend on the areas to be controlled – referred to in control theory as the feedback control loop. This might involve individual tasks, internal as well as interorganisational processes, company divisions, value chains and company networks. These are continually affected by disturbance values such as machine failures, shrinkage, quality and demand fluctuations which influence the controlled variables such as e.g. process or company performance indicators. Every interruption in the control loop leads to delays and additional disturbance values.

UC technologies, in particular automatic identification, sensor and actuator technology, are the technical foundation for the digitisation and automation of POC and POA. They are essential prerequisites for creating closed digital management loops (cf. Figure 3). Consistent digitisation of the control loop makes full automation of the control cycle possible. With a given infrastructure the costs of such a cycle, e.g. automatic rack stocktaking where rack and products communicate with one another, are lower than in the case of manual stocktaking. This cost difference not only leads to the replacement of the manual control loop by an automated control loop but also to an increase in the number of cost-effective checking cycles due to demand elasticity. A typical example is the process of stocktaking in a department store: whereas cost-intensive manual stocktaking is only carried out once per period (e.g. day, week or year) depending on the application, automatic stocktaking can be performed continuously. Pursuant to the classic rule 'you can only manage what you can measure', this continuous stream of real-time information could then be used to react better and faster to consumer behaviour.

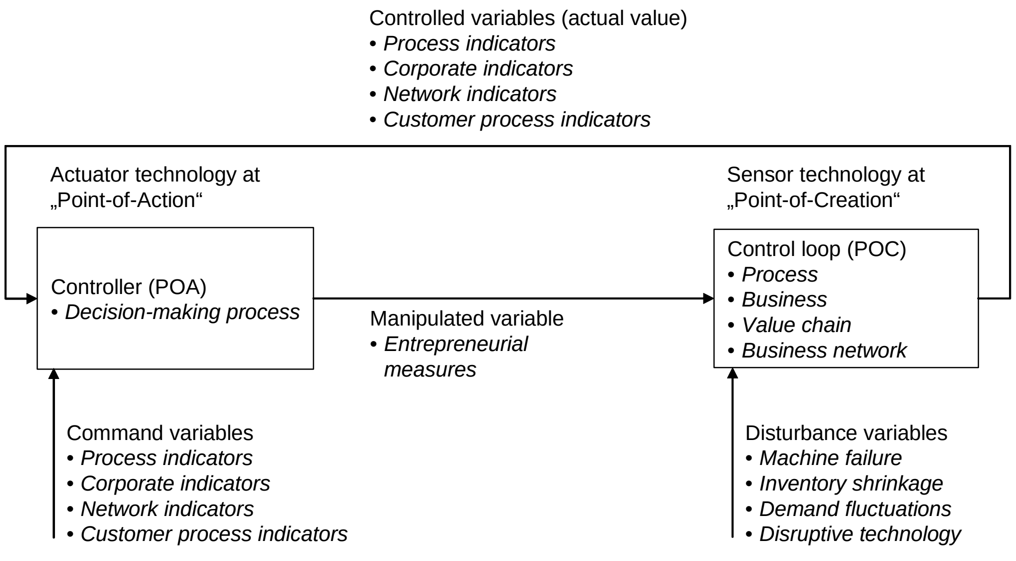

Figure 3: Digital Management Control Loop

3.4 Data view: Improvements in data quality

While the information systems used today already solve a large number of integration problems, companies nonetheless continue to work with high inefficiencies as a result of poor data quality. Examples are supply chain distortions, dead stock, theft and counterfeiting mentioned at the beginning of this paper. If a retailer knew exactly which products were out on the shelf and which were in the branch's own warehouse, he would be able to significantly increase his product availability (Alexander et al. 2002, Bharadwaj et al. 2002). So why don't retailers simply collect the corresponding data or derive them from the bar code-based check-out systems? The answer to this question goes hand in hand with the integration problem outlined above: with today's technology, full data collection from the real world is in many cases too expensive. For this reason companies have developed methods for collecting and processing data which make do with partial data acquisition and/or random checks.

The high integration costs inevitably result in decisions at the POA which are based on low-quality data. Today, decision-makers at the POA rely heavily on statistics which derive their information from processing historical data. UC can reduce the costs of integrating reality (cf. Figure 4). Sensors at the POC automatically record data from their surroundings, for example RFID readers read the identification numbers of all objects within reading distance. Actuators at the POA automatically translate the data from different POCs into value-added actions such as sending an 'out-of-stock' report to another information system or an employee. If POC and POA can collect and process data automatically, human intervention is no longer required. In what will then be a digital management control loop, data can be collected, processed and distributed in real-time.

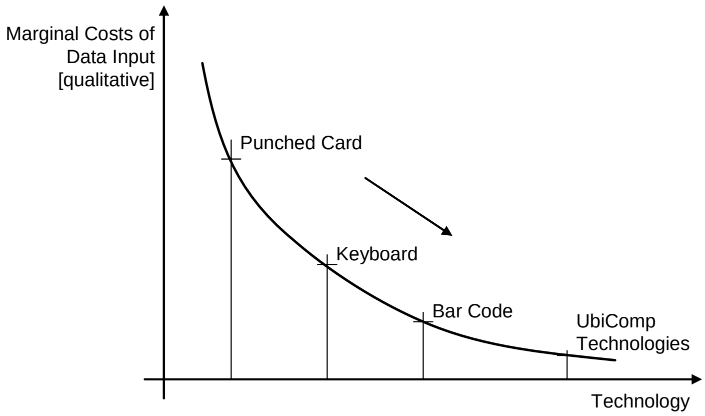

Figure 4: Falling Marginal Costs of Integrating the Real World

With the declining price of sensors and actuators, UC technologies are replacing conventional data input and output methods (Schuster et al. 2004). In addition to this substitution effect, an elasticity effect can be observed: additional sensors and actuators are employed where companies can create value from higher data quality, i.e. where the benefits from additional data quality exceed the cost. The increase in data quality takes place along the following four dimensions:

- Time (i.e. frequency of data capture and timeliness in relation to the POC),
- Object (i.e. type and number of controlled objects),
- Place (i.e. the physical space in which data capture takes place) and
- Content (i.e. diversity of the captured data and/or data types).

4 BUSINESS IMPLICATIONS

4.1 Control Tasks, Depiction Quality and Technology

The key factor in the design of new processes, products and services based on UC technologies is the quality of the depiction of the real world in the virtual world. Depiction quality extends the concept of data quality outlined above to include a model for efficient interpretation of the data: depiction quality, for example the recognition rate of an automatic access control system using video camera, is the result of data quality (image resolution) and the chosen depiction model (model for pattern recognition such as the distance between nose, eyes and mouth).

The depiction of a set of facts in the real world corresponds to the measured variable or actual value in a management control loop. Thus the quality of the depiction goes a long way toward deciding the quality of a management control loop, since for something to be managed it must be possible to measure it. New technology such as UC can increase depiction quality and consequently enable new control tasks which in turn allow new processes, products and services. Ultimately, therefore, the technology determines the maximum quality of the control task.

Each leap forward in technology adds properties which increase depiction quality and successively eliminate the limitations of the old technology, as the analogy of the visual depiction of the real world for the human eye shows. One of the first methods for visually depicting the real world was painting. To the present day, this requires an artistic skill which only few people possess; it is relatively imprecise, static, time-intensive and susceptible to error. In the 20th century, chemical photography completely replaced painting purely for the purpose of depicting reality. Through constant improvements in the technology (colour, film, zoom lens) image resolution was drastically increased and the advent of digital technology meant that images could immediately be processed. With the changeover from photograph to film, individual pieces of information became an information flow which enabled live streaming (live transmission on television such as football matches or war zone coverage by ‘embedded’ reporters, surveillance cameras, web cams) and reduced the time delay between event (POC) and spectator (POA) to virtually zero.

Example (Backroom replenishment). The before-mentioned problem of insufficient product availability in retail can be regarded as a typical example of low depiction quality. One major reason for out-of-stock situations is suboptimal shelf replenishment, i.e. products are in the store, but not on the shelf. For these reasons, retailers such as Wal-Mart and Metro seek to improve the replenishment-from-the-backroom process by placing RFID readers at the gate between backroom and store floor. The readers record the movement of cases between the two locations and thus deliver RFID data that allows for distinguishing between shop floor and backroom inventory (Whong and McFarlane 2003). From this input, the inventory management system can derive an estimate of the number of products available on the shop floor by combining the data on the flow of products from the backroom with POS data and generate an alert if shop floor inventory approaches zero.

4.2 Automation of Process Control

As a consequence of the increase in data quality, individual in-process control tasks can be performed more effectively on the basis of these data. When applied to a concrete business question it is thus important to clarify what measurements and/or depiction quality are necessary in order to be able to keep a process under control, and which technologies can be used to perform these measurements cost-effectively. Examples of control tasks of this kind are goods inspections, production control, theft prevention, proof of origin, recall campaigns, monitoring of usage behaviour and sales promotion.

Control tasks are typically performed before, during or shortly after critical process steps such as changes in ownership, for example, or events which can destroy or generate value. In a typical manual control task an operative measures the actual value in the real world and compares it with a previously defined reference value and/or the permissible upper and lower limits to be found in the relevant information system.

As an example, an employee in the shipping department of many clothing manufacturers opens up every box to be delivered and checks whether the number, type and size of the garments match the delivery note in the computer. This manual quality check is very time- and cost-intensive, and therefore more prone to error. For this reason, many companies only check a small proportion of their deliveries in detail. They trust in random measurements and try to profit from an optimal relationship between inspection and error costs.

As in many other cases, it will pay to automate the control task here if with increasing depiction quality the costs of manual control rise at a significantly higher rate than those of automatic control and the process costs including the error and consequential costs become correspondingly low. Optimal depiction quality in the case of manual control is then lower in relation to automatic control while at the same time costs are higher. However, there are also constellations where automating process controls does not achieve any added value. This applies above all if the cost gap between manual and automatic control is small and the anticipated savings are low.

The best area in which to look for process improvements based on UC technologies are therefore processes with a low level of automation and problems which can largely be solved with more precise measurement and better depiction quality. Here it is a case of the problem deciding the technology to be used and not vice versa.

Example (Semiconductor manufacturing). The production of semiconductors is a highly complex process due to its re-entrant nature and the huge variety of production steps (Billings and Hasenbein 2000). In some cases, the degree of process complexity does not allow for the use of traditional automation technology and production lots in the cleanroom have to be transported manually from one machine to another. Infineon Technologies, for example, has therefore equipped some chip fabrication facilities with a real-time identification and tracking system that uses active RFID, passive RFID and ultrasound sensors in order to track production lots in real time. In practical use, the system has led to better machine utilisation as well as drastically reduced lead times and fault rates. The complete transparency over lot locations not only eliminates search times completely but also improves the performance of operative dispatching rules.

4.3 Smart Products and Services

In addition to gradual process improvement through its use as a control instrument, UC also enables smart products and services (Allmendinger and Lombreglia 2005, Fano and Gershman 2002). In this context the term ‘smart’ expresses the fact that human beings relinquish a part of their control tasks which up to now they have performed themselves due to their capability to generate high-quality depictions to things and services. Smart products are in this sense products which achieve additional functions as a result of the new higher depiction quality through UC technology. They make their functions dependent on their immediate surroundings, on the proximity, relationship, familiarity and history of the components, means of production, wear parts, spare parts and tools with which they interact.

To derive new functions, manufacturers should regard their products as the interface to their customers and ask two questions: (a) What additional functions can they provide for the customer? (b) Which additional functions bring benefits for the manufacturer? Typical information with which a product can provide benefits for both the customer and the manufacturer is status information such as location and product identification number and/or environmental conditions. In the business-to-business field, companies use UC technologies today as a rule in means of production, e.g. machines, tools, transport containers and racking systems. The added value for the manufacturer of means of production is based on the acquired data relating to the way in which they are used by the customer or user.

Each means of production thus becomes a process interface and new source of information for its manufacturer and its users. On the manufacturer's side, information of particular interest includes that relating to functionality used, frequency and characteristics of usage of the means of production which can be incorporated in future product developments and configurations as well as in the portfolio policy. All this highlights the fact that the smart product will soon be at the center of a network of users, manufacturers and various organization units or service providers such as insurance companies, controllers, process optimizers and quality managers, and will influence the future competitor landscape in and around the process of production and use (Waldo 2002).

Furthermore, UC technology offers possibilities for linking a product with lucrative services. This is because it is often not the logic integrated into the product which provides the required customer benefit but the service linked with the smart product. Examples of services of this kind are pay-per-use billing models, automatic reordering with increasing wear of specific components or the independent quality control of food products.

Example (Risk-based car insurance). The Progressive Casualty Insurance Corporation began testing its usage-based auto insurance product 'Autograph' in Houston in 1998, and expanded the program throughout Texas in August of 1999. A unique rating methodology developed and patented by Progressive, using retrofitted Global Positioning Satellite (GPS) and cellular technology, was used to record and collect data. Data was collected by an independent vendor and forwarded to Progressive for billing. Drivers were charged according to amount of time, time of day, and place of driving. This method allowed drivers to save money by spending less time in their vehicles, especially during congestion periods when trips take the most time. A similar pilot program was started in 2003 by Norwich Union, a UK insurance company, to test the benefits of pay-as-you-drive insurance and associated services.

5 SUMMARY AND OUTLOOK

The objective of this paper was to discuss the UC paradigm from an IS perspective in order to identify its business implications. UC comprises the capability to seamlessly digital information and services into the physical world, thus enabling better process control and the creation of novel products and services. The following subsections provide conclusions that can be drawn from the previous analysis on the future consequences for corporate practice and academia.

5.1 From Integration Scope to Integration Depth

The explanations provided above illustrate that the vision of UC carries the potential to become a logical and obligatory next step in business information management. In spite of the current RFID hype, therefore, it is not a passing fad. Many of the terms currently employed may well be imprecise and will no doubt be adapted during the course of time in line with prevailing theories and marketing vocabulary, e.g. 'pervasive computing', 'ambient intelligence', 'context-aware computing', and 'silent commerce'. Whichever name is used, the UC concept will nonetheless introduce a new quality in information management. While the classic development of information management from local, isolated systems to interorganisational e-business systems has first and foremost expanded the network of data captured in order to improve organisation – after initially covering individual departments, it now encompasses entire value chains – UC makes the data capture network more finely meshed.

Whereas the e-business trend extended the scope of integration, the UC trend increases its depth (cf. Figure 5). With the increase in depiction quality, UC allows a more finely grained management of mass resources: individual products in place of the usual product categories; transport containers in addition to the production machines already managed; time and location points instead of imprecise time and location areas; environmental information in addition to object information. UC thus also makes it possible to manage low-value assets cost-effectively.

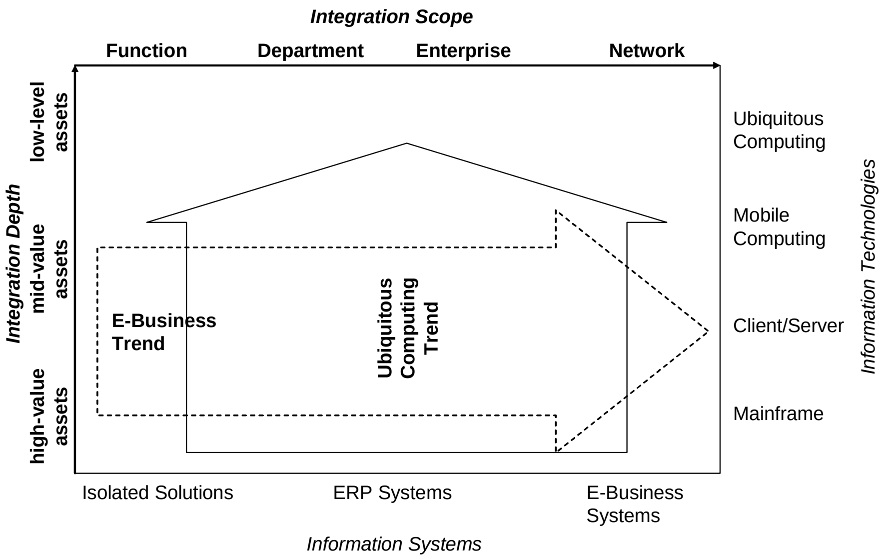

Figure 5. Integration Scope and Depth

5.2 From closed loops to open loops

Analysis of the UC solutions implemented to date in the area of RFID shows that the increase in integration depth typically begins in closed loops. The reason for this is firstly the fact that it is easier to push through innovative projects within an organisation than in a network with several equal partners who pursue different interests and have different budgets at their disposal. Hierarchical pressure is simply easier to generate than win-win situations in a business network. Secondly, calculating the return on investment for UC solutions is not a trivial task in many cases. UC solutions require a new infrastructure consisting of IT equipment, communication networks, middleware and databases, the short-term and quantitative benefits of which are often just as difficult to calculate as those of a new plant road. The decision for or against RFID, for example, is a decision for or against a new infrastructure (Sarma 2004).

Challenges related to the distribution of costs and benefits of UC solutions are a third reason in favour of initiating adoption within the boundaries of a business's own organisation. In closed-loop applications, both costs and benefits arise within the same balance sheet structure. In open systems, on the other hand, costs and benefits are spread across different organisations. As a rule, resolving the questions of 'Who gains which benefits? Who has to bear what share of the equipment, infrastructure and transformation costs?' requires a lengthy political process which is shaped by the power distribution within the network but also by uncertainty as to the real benefits.

Once initial experience has been gained, for example in internal container management, and know-how in dealing with UC technology built up, the company is in a good position to take part in open solutions. However, this will only be the case if it has opted for the right standards. Containers and products which can only communicate internally are as much use as an internal telephone in international business. For this reason, active participation in standardisation initiatives is essential for initial and early adopters of RFID technology.

5.3 Services Follow Processes and Products

A large number of companies might be using the high depiction quality of UC technology in a first step merely to gain better knowledge of their de facto processes ('When and where is theft taking place?') and de facto use of their products ('What temperatures and acceleration rates is the product actually exposed to?'). They will be most probably using UC merely as a monitoring tool, whereby the facts obtained then form the basis for analysing the problems and possibilities for designing improved processes and products.

It is becoming increasingly apparent that the development of smart services will only take place in a second phase. It presupposes not only an infrastructure which is at least regional (in other words, the 'internet of things' (Das and Harrop 2001) – or from the point of view of the telecommunications company, the telephone of things), but also previous experience in dealing with higher depiction quality, in particular with automated process controls and smart products. Thus, for example, a service which provides football fans, trainers and players with information on ball contact, shot speed, opponent contact and kilometers run per half, will not only depend on smart footballs and smart football boots but also on a functional infrastructure in all major stadiums. Thus, the interdependencies between product, process, service and infrastructure development are increasing.

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