Published October 1, 2003. Distribution restricted to Sponsors until January 1, 2004.

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Ubiquitous Computing: Why Auto-ID is the Logical Next Step in Enterprise Automation

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ABSTRACT

This paper identifies and analyzes potential business benefits of ubiquitous computing (UbiComp). Its aim is to challenge whether the growing visibility of topics such as ubiquitous or pervasive computing, automatic identification (Auto-ID) and radio frequency identification (RFID) can be justified from a business perspective. To do so it analyzes the business contribution of existing UbiComp applications, reconstructs their development phases, introduces the business-relevant base functionalities and discusses implications for the design of products, processes and services using UbiComp applications. The creation of an alternative and rather cost-efficient machine-machine relationship between already established information systems and the real world things they try to manage has been identified as the main source of business benefit. However, before businesses can systematically leverage all potential benefits, some technical and political questions, such as creating robust solutions and solving privacy issues, have to be answered.

Key points for management

Ubiquitous computing technologies make it possible to improve business processes in the areas of supply chain management, product life cycle management and customer relationship management. It also enables new business models such as leasing or pay per use.

- Ubiquitous Computing (UbiComp) is a logical next step in business computing.
- The associated global standardization required in the area of automatic identification (Auto-ID) is advancing at a swift pace.
- Software companies such as SAP are already developing infrastructure software to support UbiComp applications.
- Particular importance must be given to the issue of privacy when designing applications involving consumers.

Keywords

ubiquitous computing, pervasive computing, applications, integration

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Ubiquitous Computing: Why Auto-ID is the Logical Next Step in Enterprise Automation

Contents

1. STARTING POINT AND PROBLEM

As a discipline, ubiquitous computing (UbiComp) has become progressively more visible over the past two years [AbMy00; Norm98; Saty01; Weis91]. Evidence of this trend is to be found in newly established journals (e.g. IEEE Pervasive Computing), conferences (e.g. UbiComp or Pervasive), summer schools [Midk03] and research programs in which researchers from the fields of distributed systems, human-computer interfaces, sensor technology, etc. and increasingly from information management exchange and benchmark their ideas.

Individual UbiComp technologies have today reached a level of maturity which allows the development of business applications. In the area of automatic identification, for example, standardization is already well advanced [Auto03; Forr02; Shar01; Wolf01]. At the same time the political discussion of privacy issues has begun [JeRo02; Lang01]. Both developments are indications that the technology has gained a foothold in business [Utte94; Gain03; Busi00].

Most applications-oriented UbiComp publications continue to describe scenarios involving consumers, referred to as “business-to-consumer” applications. 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, language teacher and purchasing agent for the next generation of children [KMGW00; NeSL00]. 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 UbiComp lie in the area of “business-to-business” scenarios. This also explains why so many IT companies are taking an interest in this topic [Kind01, Acce02]. IBM, for example, set aside a research budget of 500 million US dollars for this area [Bude01].

Nonetheless, the authors are not familiar with any theoretically and empirically backed reports on the subject. These are necessary, however, to ensure that UbiComp does not develop into a fashion trend – comparable to the exaggerated hopes previously placed in artificial intelligence, expert systems or e-Business – which promise much more on paper than they can actually deliver in reality.

The aim of this paper is to contribute toward closing this gap. It identifies and analyzes the business contribution of existing UbiComp applications, reconstructs their development phases, highlights the potentials for new business processes and models based on UbiComp and discusses implications for the design of products, processes and services using UbiComp applications.

The findings mentioned in this paper stem from the literature as well as from numerous research and development projects in industry for which the authors provided scientific support, from idea generation and conception, operational efficiency analysis and technical feasibility study through to the demonstrator, in some cases going as far as the pilot implementation.

This paper considers above all solutions which use the technologies radio frequency identification (RFID), automatic identification (Auto-ID) and sensor technology. RFID is a radio technology which allows small data volumes (1 bit to around 30 kilobytes) to be transported cost-effectively through the air between a transponder and an antenna. In 2003, a transponder costs between 8 euro cents and 20 euros, has a range of between 2mm and 100m in combination with the right antenna, comes in sizes ranging from a grain of sand (0.4 x 0.4 x 0.4mm) to a mobile telephone and draws its power for processing, storage and communication from a built-in battery (active transponder) or the electromagnetic field of the antenna (passive transponder) [Matt03; BCLM03].

Auto-ID technology gives RFID an internationally standardized numbering system for all real and thus potentially smart things plus an infrastructure which makes it possible to communicate with RFID transponders across the globe. As from 2003, the dissemination of Auto-ID technology is being driven by EAN/UCC, the organization which has established the barcode standard for over 25 years [Auto03]. Sensor technology refers to the fact that RFID transponders and antennas are equipped with sensors. Sensors permit the automatic measurement of a large number of environmental conditions such as temperature, moisture, brightness, acceleration, chemical composition, pressure, noise, etc. The data obtained from these sensors can be transported to the point of action via an Auto-ID infrastructure.

2. SOURCE OF BUSINESS BENEFIT

UbiComp is a logical next step in the development of business computing. Integrated information systems like R/3 from SAP have linked individual functions and departments within companies, and thus enabled consistent business processes. The Internet and e-Business systems such as supply chain management systems or electronic markets have extended these processes beyond the boundaries of organizations and support the management of business networks.

With UbiComp, business computing is destined to undergo its next step towards integration. While integrated information systems and e-Business systems aim to link an ever greater number of applications and databases, UbiComp sets out to integrate these applications and databases with the real operational environment such as the warehouse. UbiComp will close what in many cases today is the very expensive gap between information system and reality. Sensor technology (and actuator technology) enables UbiComp -based systems to recognize (and/or initiate) changes in conditions in the real world automatically [AbEG02]. They make their decisions on the basis of fact-based real-time data taken from reality and not on the basis of updated accounting values from information systems. The consequence is new process capabilities which can lead to cost savings, quality improvements and new business models.

Up to now, research and practice have concentrated primarily on the networking of businesses, processes, information systems and humans, and try to eliminate media discontinuities with the aid of information technology (cf. Table 1) . A frequently quoted example of media discontinuity is the multiple registration of an order in different business information systems within a value chain. A media discontinuity is comparable to a missing link in a digital information chain and is a contributing factor to the slow speed, intransparency, error susceptibility, etc. of intra-organizational and inter-organizational processes.

UbiComp technologies have the potential to prevent the discontinuity between physical processes and the associated information processing. They enable a fully automatable machine-machine relationship between real things and information systems by equipping the former with a "minicomputer". 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. Physical resources can communicate with internal and external computer networks without human intervention and thus ultimately permit continuous process control on the basis of hard, real-time information obtained from reality [KäHo02].

Table 1

MEDIA DISCONTINUITIES AND COMPANY INFORMATION SYSTEMS

Where do media discontinuities occur?	Information systems to overcome media discontinuities
– in individual company functions such as finance or production planning – in intra-organizational processes – in inter-organizational processes – in the linkage of information systems with events in the real world	– function-oriented standard software packages such as e.g. financial packages or PPS – enterprise resource planning systems such as e.g. R/3 from SAP – inter-organizational systems such as e.g. e-Procurement and supply chain management systems – UbiComp applications, e.g. based on radio frequency identification (RFID) technologies and sensor networks

3. DEVELOPMENT PHASES OF BUSINESS UBICOMP APPLICATIONS

Mark Weiser has described UbiComp as the opposite of virtual reality. The goal of virtual reality is the almost exact depiction of an extract from the real world in digitally processable models, such as for the purposes of simulation [Bend98]. In virtual reality, model (e.g. flight simulator) and real world (e.g. flight) can coexist without interdependencies.

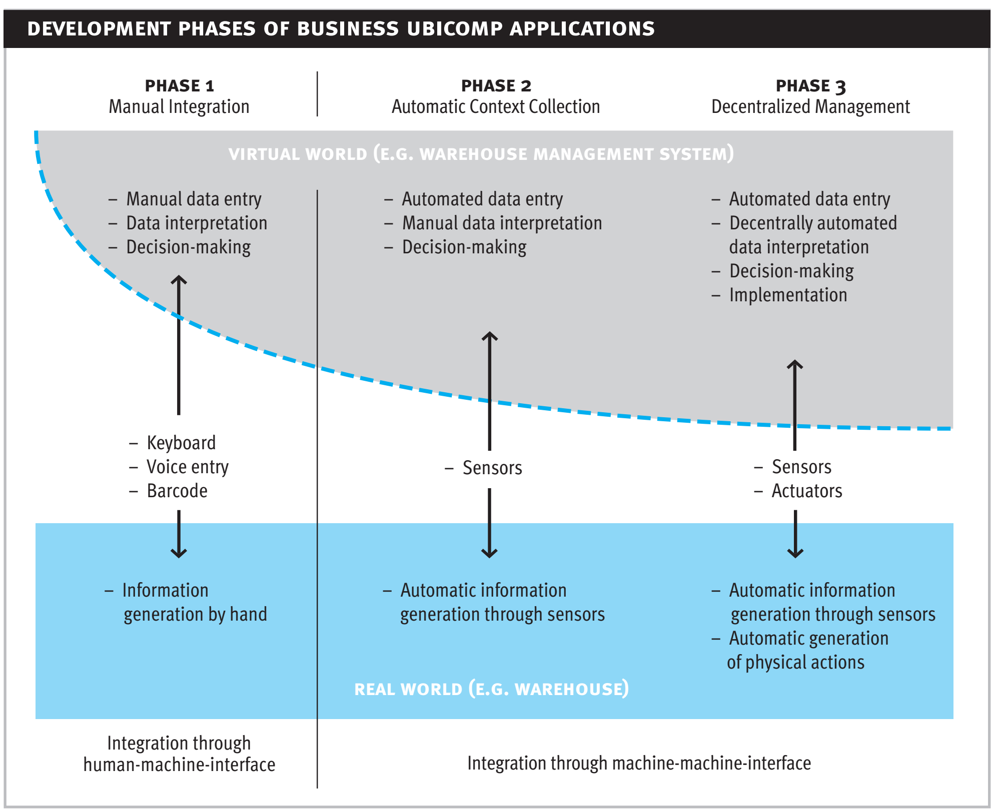
The goal of UbiComp is the functional enhancement of the real world with the aid of information processing. A UbiComp application always consists of a real and a virtual side which are inseparable from one another. The real world dominates while the virtual world takes on a supporting role. In UbiComp applications virtual worlds always have a direct, immediate relationship with reality.

Active, i.e. battery-operated, transponders, for example, can be equipped with different sensors to suit the application for the purpose of capturing and transmitting the status of their context (mother object, environment and neighbor objects) immediately at the point of action. When temperature sensors permit the continuous monitoring of a cold chain for food products and acceleration sensors in automobiles automatically alert the police and ambulance services, the virtual world of information processing is increasingly shifted into reality, for example into the visible world of physical transactions. The path to such a world with ubiquitous computers can be described in three phases (cf. Figure 1).

Phase one is characterized by manual and model-based information generation and/or decision-making. Phase two is distinguished from phase one by automatic context collection which generates a broad, fact-based database for decision-making. Phase three represents the increasing delegation of decision-making and implementation to objects in the real world enhanced by information processing, referred to as “smart things” [GeSBoo].

Figure 1:

Integration costs and integration technology



3.1. Manual Integration

Phase one describes business computing where the link between the virtual and the real world is exclusively provided by humans. Humans define a depiction of reality, record it in databases and procedures, enter the data manually and interpret the results.

Nowadays, for example, facility managers follow inventory movements in office buildings, maintenance work on radiators and air-conditioning systems, and the whereabouts of building keys with the aid of computer-aided facility management systems (CAFM systems). The initial recording of the objects to be managed, determination of the correct location and stocktaking (= matching reality with the data in the CAFM system) are still performed by human employees. They ensure that the information on a relocated table is updated, maintain the cost center and location models to depict where the table belongs and interpret the shortfall shown by the stocktaking. Integration between the virtual and real worlds is performed manually.

3.2. Automatic Context Collection

UbiComp enables companies to capture process information automatically with low marginal costs. With decreasing measuring costs per measuring point, the number of measuring points used will increase since the process managers responsible for process quality and process improvements are interested in obtaining real-time data which are differentiated and reflect the real world as far as possible.

Instead of relying on humans to update data on reality in models, data collection technologies generate facts on the basis of real data. These automatically collected facts provide a new boost for the application of method sets such as e.g. Six-Sigma [HaSc99] which is used throughout General Electric and also at Ford to improve processes. With UbiComp technologies an ever greater number of processes become manageable and improvable as information generation is directly connected to the concrete actions in the real world without modeling and without the time-intensive entry of information.

In tunnel construction, for example, certain temperature curves are necessary for optimal concrete hardening of the tunnel walls in order to guarantee the strength of the concrete. Using transponders with integrated temperature sensors cast into the concrete, UbiComp can be employed to monitor the temperature curve continuously and without expensive measuring equipment, thus ensuring the strength of the concrete walls with less time and effort. The temperature curve can be queried at any time by radio. Process errors which would lead to cracks in the concrete are minimized. The process efficiency of hardening is increased and subsequent operations can begin several hours earlier.

3.3. Decentralized Management

The third phase on the path to UbiComp-assisted processes is characterized by the delegation of decision-making. UbiComp enables smart things to “comprehend” situations themselves and to make and implement decisions in accordance with their configuration. This alleviates central resources such as data storage, processors and databases.

Smart things allocate their handling or production requirements to the respective handling equipment or production machines without having to involve a central control computer each time. At Seagate, semi-finished products carry transponders with a customer-specific checklist for production and assembly. This information helps to manage the production process flexibly, check the completeness and correctness of the individual production steps and rapidly pinpoint the source of any problem [Ferg03].

If this development is thought through to its logical conclusion, then it is no longer possible to separate actions in the real world from those in the virtual world. The change in the position of a batch in a rack, for example, initiates an update of the information memory. The rack must decide for itself whether a batch belongs there or is already so far away that assignment would no longer be valid. Handling in the real world merges with information processing in the virtual world. Smart things depict relationships to other smart things which are observable in reality – for example geographical proximity – also in terms of information [Kaih01].

4. NEW BUSINESS PROCESSES AND MODELS THROUGH UBICOMP

The digital management control loop provides a model to explain the fundamental implications of UbiComp technologies for business processes and models. It helps to recognize that business-motivated UbiComp systems are used primarily to automate cost-intensive continuous tasks at the interface between established information systems and the real world, and thus not only change business processes but also enable new business models.

The classification of continuous tasks into basic tasks is the result of analyzing numerous UbiComp applications. It reduces the applications to the new functions made possible by UbiComp and structures these on the basis of master and rule data of the underlying applications.

4.1. Automation of the Management Control Loop

The fusion of the real world with the virtual world makes it possible to close the digital management control loop, as described below, based on the model of the real-time business (cf. Figure 2). In the ideal real-time business, information instantaneously becomes available at the point of use or "point of action" (POA) as and when it arises at the "point of creation" (POC) [FlÖs03]. Both the POC and POA can be assigned to different organization units and thus necessitate intra-organizational and inter-organizational information flows. The POC can, for example, be a retailer's scanner 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.

POC and POA can be part of the real or the virtual world. When the sales person pushes a packet of jam jar sealing rings across the check-out desk or when a traffic jam forms on one of the motorways in the Stuttgart region, these events generate information which has to be digitized in information systems before it can be processed and therefore first has to be entered. The POA remains in the virtual world if the retailer's retailing system merely triggers a purchase order via the procurement system in the supplier's sales system where it must be manually processed to create a sales order. If, on the other hand, the retailing system intervenes directly in the supplier's production management, then the POA is the factory where the physical world changes as a result of the information from the POC.

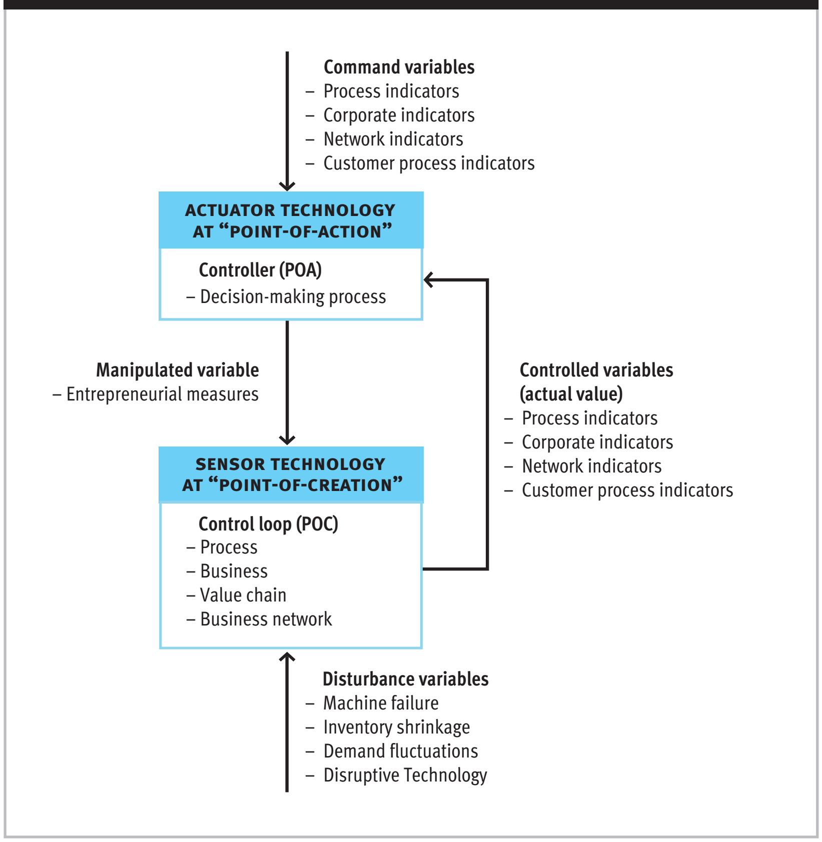
As can be seen from the example of the retail trade, a large number of POCs and POAs can be identified in the supply chain – always at the precise moment when information is created or used. The choice of POCs and POAs will depend on the areas to be controlled – referred to in measuring and control technology as the control loop. This might involve individual tasks, internal as well as inter-organizational processes, company divisions, value chains and company networks.

These are continually affected by disturbance variables such as machine failures, shrinkage, quality and demand fluctuations which influence the controlled variables (actual values), such as e.g. process or company performance indicators, and require real-time management. At the POA the decision-maker (controller) compares target values (command variables) with actual values and defines measures (manipulated variables) aimed at influencing the control loop so that the controlled variables meet the targets.

Every interruption in the control loop leads to delays and additional disturbance variables. Processes, businesses and business networks then cannot be managed in real time. UbiComp technologies, in particular automatic identification, sensor and actuator technology, are the technical foundation for the digitization and automation of POC and POA. They are essential prerequisites for creating digital management control loops.

Figure 2

DIGITAL MANAGEMENT CONTROL LOOP



4.2. The Real World of UbiComp Applications

Consistent digitalization of the control loop makes full automation of a 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 [RFID03], 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 automatic control loop but also to an increase in the number of cost-effective checking cycles due to demand elasticity [MaCr94]. 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.

UbiComp solutions assume cost-intensive tasks at the interface between information systems and the real world in an infrastructure which should have the capability to perform these tasks fully automatically and therefore more cost-effectively and on a continuous basis. These basic tasks are part of numerous processes which involve the real world, i.e. living and physical things. As a rule, these are continuous tasks which are always active, even if mostly in the background. Their execution is correspondingly complex. Nowadays, these continuous tasks are only performed sporadically for reasons of cost and time. The consequences can be quality problems and theft. The most important basic functions include automatic identification, positioning/track & trace, sensor technology, quality assurance, billing, risk assessment, sales support, control and actuator technology.

- The aim of **automatic identification** is automatic linkage between the real and the virtual world. Automatic identification (Auto-ID) eliminates the media discontinuity between things and their depiction in information systems. A standard infrastructure for automatic identification is currently under development [Auto03].

- **Positioning/track & trace** links identification with its geographical location. With the aid of the basic task track & trace all business processes are continuously provided with transparency regarding the whereabouts of their smart things.

- With the basic task **sensor technology** smart things collect information about their status and their environment. Examples of such sensor data are acceleration, temperature, humidity and the chemical composition of the surrounding medium. Companies can use sensor technology e.g. for the continuous automatic collection of data relating to use.

- Another basic task is **quality assurance**. This links information about smart things (e.g. identification number, position, temperature) with rules which on the one hand describe quality limits and on the other hand record what is to be done if those limits are exceeded. On the basis of UbiComp technologies many quality assurance tasks such as anti-theft protection, cool chain monitoring and damage prevention can be fully automated and thus operated at a commercially acceptable cost: process quality is increased.

- The basic task **billing** uses the information collected by smart things to realize new billing models. It is only when there is continuous participation in the life of a product that pay per use, for example, becomes possible. UbiComp allows pay-per-use and leasing models for products which up to now could only be sold. The financing risk is passed from the customer to the manufacturer who nonetheless profits from continuous income, utilization data and higher customer retention. At the same time, UbiComp also permits pay-per-damage models, i.e. the assignment of damage sustained by a smart product somewhere in the supply chain to the originator. And ultimately, UbiComp could also contribute toward earn-by-contribution, i.e. the originator-based allocation of product-related earnings to partners involved in value creation.

- **Risk assessment** also takes on new dimensions when the objects to be assessed can automatically collect and process information. A US insurance company has very successfully begun to charge premiums depending on actual mileage and the types of road used by the driver – the data are collected by the GPS in the insured vehicle – (pay per risk).

- Unlike billing, the basic task **sales support** uses identification, position and sensor data for situation-based marketing. Users of such systems receive sales support information which is tailored to the user and the current situation [RFID03].

– The basic task **control utilizes** the data on status and environment for the decentralized management of e.g. production processes [Esor98]. Smart semi-finished products carry data on production steps yet to be performed and already completed, and help to prevent delays or incorrect handling, or to identify them as quickly as possible. The basic task control closes the digital control loop with the communication between the smart semi-finished products and higher level control system such as a production planning and management system.

– The basic task **actuator technology** only differs from control in the way in which decisions are implemented. With the aid of actuator technology, a smart thing such as a small, robotics-enhanced vacuum cleaner can exert a direct influence on its real environment without the help of a higher-level information system.

Table 2 shows the basic tasks identified along with the data required to fulfill them. Collection and processing of these data are the task of the UbiComp systems. The basic tasks can be divided into three categories: for the first category of tasks (automatic identification, positioning and sensor technology) UbiComp systems merely have to collect data and pass them on to higher-level systems which evaluate these data periodically or as required. In the second category (quality assurance, billing, sales support, control) evaluation is performed continuously using rule data. Here, UbiComp systems process business logic. Actuator technology forms a separate category. The direct implementation of decisions in the real world, e.g. by means of mini-robotics, distinguishes it from the other categories.

Table 2: Basic Task and their data

BASIC TASKS	MASTER AND RULE DATA
Category 1: Data Collection	
Automatic identification	Object ID
Positioning / track & trace	Object ID, position
Sensor technology / market research	Object ID, position, sensor data
Category 2: Continuous Decentralized Evaluation	
Quality assurance	Object ID, position, sensor data, notification rules
Billing	Object ID, position, sensor data, billing rules
Risk evaluation	Object ID, position, sensor data, evaluation rules
Sales support	Object ID, position, sensor data, info push rules
Control	Object ID, position, sensor data, control rules
Category 3: Direct Implementation of Decisions	
Actuator technology	Object ID, position, sensor data, actuator rules

These basic tasks lead to increased quality and efficiency above all in the supply chain management (SCM), product life cycle management and customer relationship management (CRM) processes (cf. Table 3). In the area of SCM, transparency in respect of the objects in a value chain plays a major role in minimizing lead time, inventory, theft, forgery and damage, e.g. through overheating or lapsing of an expiry date, and in increasing product availability [Busi02; IDTe02]. In product life cycle management the linkage of every smart product with its homepage ensures improved subprocesses in the areas of proof of origin, decomposition, recall campaigns, reuse, maintenance, repair, wage accounting, etc. In the area of CRM, payment models, market research, customer analyses and cross-selling activities take on a new quality.

Table 3

IMPLICATIONS OF UBICOMP FOR BUSINESS PROCESSES			
Process	Supply Chain Management	Product Life Cycle Management	Customer Relationship Management
Focus	Supply chain efficiency	Transparency over the entire life cycle	Effective customer care
Subprocesses, subprocess goals	Inventory minimization Reduction in lead times Flexibilization Transport tracing Risk minimization Damage minimization Theft prevention Forgery prevention	Product traceability Decomposition Recall campaigns Reuse Maintenance Repairs Wage accounting	Consumer behavior Payment models Sales promotion and ubiquitous points of sale Cross-selling Monitoring Market research

5. IMPLICATIONS FOR PRODUCT, PROCESS AND SERVICE DESIGN

Central to the basic tasks is the functional communication capability of smart things. Utilizing this communication capability is the task to be fulfilled when designing UbiComp-based products, processes and services.

5.1. Functional Communication on the Basis of UbiComp Technologies

Each product communicates with its user at the relationship and content level [WaBJ67]. One benefit of communication at the relationship level can be the effect which an Italian espresso machine has on the user who prefers its shape to that of a German coffee-maker. The maximization of aesthetic benefit is a classic goal of industrial design. It helps both the customer, who feels good in the vicinity of the machine, and the manufacturer, who is able to defend or improve his market position.

Product development are essentially responsible for creating the functional benefit of a product. Their goal is to maximize the added value perceived by the user. Communication design and function design are thus inseparable. The more varied the functionality of an object, the more wide-ranging its need to communicate: while today's hammer does perfectly well without LEDs, acoustic signals or mini-display, things with a wider range of functions – in addition to coffee machines –VCRs, mobile telephones or automobiles have to rely on communication tools. This relationship between functional variety and communication requirement implies an inversion of the argument: UbiComp enhances communication capability and thus the perceivable added value derived from additional functionality.

This leads to the following design question: what are the new additional functions which provide business benefits thanks to UbiComp? How can the manufacturers of things identify such functions?

One approach to answering this question is the challenging theory that "good products want to communicate". To be more precise, this should read: manufacturers want their products to create competitive advantages through communication. They use the product as an agent which they endow with the capability of providing its environment, in particular customers but also the manufacturers themselves, with added value through communication (see Figure 3).

In order to derive the new functions, manufacturers see their products as an interface to their customers and ask the following two questions: which additional functions can they provide for their customer? Which additional functions will provide added value for manufacturers?

Typical information with which a product can provide added value for both customer and manufacturer is status information such as position and product identification number or environmental conditions. A hammer, for example, might advise its owner where it is located and its manufacturer how often it has been used. If the tool is located in the "wrong" toolbox it would automatically report the fact. Also, when leaving a predefined zone, the smart tool notifies the parties concerned, thus contributing to anti-theft protection, for instance.

In the business-to-business area, companies use UbiComp technologies as a rule nowadays for means of production, e.g. machines, tools, transport containers and racking systems. The added value for the manufacturer of the means of production is based on the data obtained on the way in which they are used by customers and users. This is the case, for instance, if a transport container continuously reports its position and utilized capacity, a drill reports its operating status and the functionality used, and a racking system continuously reports current occupancy and turnover.

Each means of production thus becomes a process interface and "new" source of information for its manufacturer and its users. Of particular interest as far as the manufacturer is concerned is information on the 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. Capacity utilization, transport and downtime for transport containers, pallets and trucks can be accounted for, or rotational speeds and utilization peaks for drills collected for the purpose of developing more productive means of production or complementary products to enhance productivity or provide the user with more suitable means of production.

Of interest to the user are e.g. the location, capacity utilization and the productivity achieved with a tool for a particular task. In addition, benchmarking and process information regarding various applications of the means of production can be obtained automatically and reported to the user. The smart rack "knows" how well its user organizes and operates the warehouse. Added value is achieved in the form of a built-in analysis capability where critical process statuses are acquired through sensor and identification technologies and can be suitably displayed on the object itself. In future, a transport container will automatically report that it has spent too much time without being moved or that its load is overheating. Additional services in the area of process benchmarks are provided in direct connection with these smart "means of production". Means of transport equipped with UbiComp technologies will offer the possibility of comparing utilization profiles with other users and pointing out process inefficiencies. The role of "process optimizer" and production equipment manufacturer will increasingly merge with the use of "smart means of production".

In addition to analysis, monitoring of the production or transport process is particularly important for quality and risk management as well as for controlling. At the same time, physical damage can be minimized through the consistent recording of usage of the means of production, e.g. in-transit shock measurement and temperature monitoring, and the pay-per-damage model applied. Smart means of production include elements of the approval process and enable e.g. a differentiated split of insurance premiums for physical damage between various customers.

This all clearly shows that the smart thing "means of production" will soon be at the center of a network comprised of users, manufacturers and different organization units or service providers such as insurers, controllers, process optimizers and quality managers, and will influence the competitor landscape of the future in and around the production and utilization process [Wald02].

Figure 3:

1 – Process Optimization
– Benchmarking
– Quality Management

2 – Frequency of Use
– Functionality Used
– Operating Data

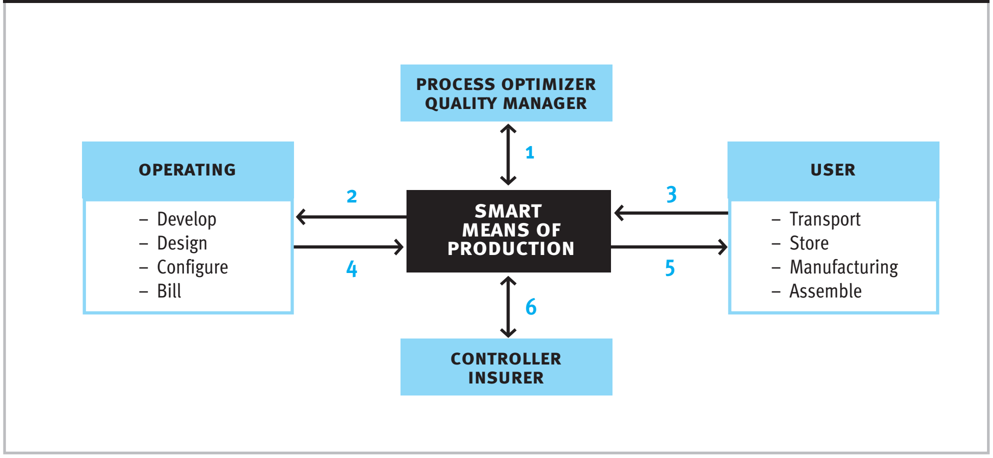
3 – Operation/Use
– Downtimes/Failures

4 – Means of Production Management
– Online Services
– Leasing

5 – Productivity Increase
– Alert
– Positioning

6 – Stocktaking
– Depreciation
– Damage Assessment
– Risk Assessment

NETWORK CENTERED ON THE SMART THING



5.2. Fusion of Product, Process and Service Design

The investment in the “smartness” of things must be reflected in a change in the process since added value for the customer is only created through process improvements. The analysis of product and service development must therefore be meshed with process design [FaGe02]. Smart furniture, for example, supports the process of installation and assembly. The user no longer needs a set of instructions to assemble a piece of furniture which is supplied as individual components. UbiComp is integrated into the components in the form of simple microchips which ensure that parts can only be fitted where they belong. A warning is given in the event of errors [AnMS02].

The starting point for integrated product/process development must always be the added value for the customer. This is often created by simplifying the process through which the customer passes to solve a problem, such as assembling a piece of furniture or supplying retailers with fresh goods.

Smart things rationalize a customer process either by supporting the coordination of individual tasks in the process (e.g. pick-to-light application: a product identifies itself through a light signal) or by performing entire tasks (e.g. registering a goods receipt, anti-theft surveillance, checking correct assembly, etc.). They utilize knowledge of their surroundings and decide decentrally by means of routines stipulated by the manufacturer or selected by the customer.

The business goal of simplifying the customer process is only of limited relevance, however, in the area of games. As can be seen from the Tamagotchi example, a smart egg can also create added value when it enriches its user’s life or, to take a more objective view, complicates it by encouraging social sensitivity. It remains to be seen whether smart things trigger greater emotional loyalty in the business context due to their enhanced communication capability in comparison with “dumb” things. The warehouse operative who finds the time required to find case A738 drastically reduced because it flashes is pleased about the smart, autonomous and cooperative case and may react emotionally in a similar way to the consumer, such as the child who is addressed by its doll when entering the room.

When smart products assume entire tasks, e.g. quality assurance tasks such as temperature monitoring, the customer is outsourcing those same tasks to the products and if necessary to the product manufacturer. Outsourceable tasks of this kind are candidates for services which the manufacturer of smart things can offer in addition. Services linked to smart things reduce complexity for the customer and simplify the customer process. At the manufacturer’s end, they can generate regular income, increase customer retention and the opportunities for identifying additional business potentials. Examples of such services are to be found in areas such as billing, use monitoring, anti-theft and leasing.

It is quite conceivable that the market will require more and more additional services of this kind to become a standard part of established smart products [Utte94]. The first signs of this development are to be found among the automotive manufacturers, for instance, who are increasingly installing navigation and anti-theft services [Kaer02].

6. SUMMARY AND OUTLOOK

UbiComp enhances the real world with information processing units and thus offers the possibility of replacing cost-intensive things-human-machine relationships with cost-effective machine-machine relationships. This change permits the relatively simple automation of business tasks which up to now could only be automated with great difficulty. These include identification, positioning, quality control, market research and pay per use.

However, a large number of problems which were not dealt with in this paper must first be resolved before the benefit potentials outlined can be realized [DaGe02]. It is precisely these unanswered questions which point to possible future paths for technical and business research in the area of UbiComp. Research questions of a technical nature include the scaleable architecture of a global UbiComp infrastructure [LyYo02; BaBe02; Pier01], the integration of UbiComp systems in existing system landscapes, the enhancement of the Auto-ID and positioning function with sensor technology to form sensor networks [KhKP00] or with actuators, a description language for UbiComp-specific data, the management of UbiComp data, security aspects [StAn02] and other methods to reduce the cost of minicomputers and readers.

As yet unresolved business issues include privacy, the operational efficiency of UbiComp applications, technology adoption paths for a UbiComp infrastructure, industrial services based on UbiComp and billing models.

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