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Ambient Intelligence in the Production and Retail Sector: Emerging Opportunities and Potential Pitfalls

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***Abstract*—** This paper provides an introduction into the evolution of information and communication technology and illustrates its usage in the work domain. The paper is sub-divided into two parts. The first part gives an overview over the different phases of information processing in the work domain. It starts by charting the past and present usage of computers in work environments and shows current technological trends, which are likely to influence future business applications. The second part starts by briefly describing, how the usage of computers changed business processes in the past, and presents first Ambient Intelligence applications based on identification and localization information, which are already used in the production and retail sector. Based on current systems and prototype applications, the paper gives an outlook of how Ambient Intelligence technologies could change business processes in the future.

***Keywords*—** Ambient Intelligence, Ubiquitous Computing, Business Applications, Radio Frequency Identification (RFID).

I. From Mainframe Computers to Intelligent Objects

THE role of computers within the workplace has dramatically changed within the last decades. The increase in processing power and availability did not only influence the way people use computers for their daily office tasks, it also gave rise to fundamentally new forms of work organization within, and also between companies.

A. Information Processing in Work Environments

Only 30 years ago, a company usually had a single mainframe computer, which cost several millions, needed a whole computing center to be operated, and was jointly used by all employees of the company [52, 56]. With smaller and more affordable computers becoming available in the early eighties, the age of personal computing began. Computers became widespread office tools in most companies, and over the years each user was working on his own personal computer. Today, the initial numerical relation between users and computers has inversed [58]. Each user has a least one personal computer and uses a number of additional micro-processors embedded in everyday objects, like telephones and cars. This age of ubiquitously available computing devices was identified by Weiser [94] already in the early 1990s as the third wave of computing. He envisioned a transition towards calm technologies that recede into the background of our lives and assist us in our everyday activities.

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TABLE 1: Waves of computing (see [77]).

Waves of Computing	Characteristics
1960 ~ 1980 (first wave)	▪ mainframe era ▪ one computer, many people
1980 ~ 2000 (second wave)	▪ personal computing era ▪ one person, one computer
since 2000 (third wave)	▪ ubiquitous computing era ▪ one person, many computers

Networking probably brought the most significant change in the usage of personal computers during the last years [4]. Table 2 shows, how networking evolved since its introduction in the early 1970s. During this time it changed from an experimental research network, primarily used by computer scientists, to what is known today as the world-wide web and used by billions of users for e-mail communication and web browsing [54, 55].

TABLE 2: Evolution of the internet over the last decades (see [49]).

Decade	Primary Usage
1970s	▪ experimentation and research network ▪ mostly used by programmers for remote login and data transfer
1980s	▪ mostly used in research ▪ primarily application was one-to-one communication
1990s	▪ introduction of the world wide web ▪ used by the public for e-mail communication and web browsing, which resulted in a multiplication of data traffic

As networking technologies and bandwidth are constantly improving, a variety of new services became available within the last years. After web-based multimedia applications in the 1990s, broadband network appliances became widely available within the last years. And

according to studies of large electronic companies [77], the transition to a ubiquitous network society will take place within the next five to seven years.

TABLE 3: CURRENT TRENDS BASED ON NEW NETWORKING TECHNOLOGIES (SEE [77]).

Time Span	Applications
1995 ~ 2000	multimedia appliances
2000 ~ 2005	broadband network appliances
2005 ~ 2010	ubiquitous network appliances

For the future, an even more dramatic shift in the usage of the internet is anticipated. While people today communicate via browsers with machines (web servers), the internet of the future is expected to be used principally for machine-to-machine communication, or rather, object-to-object communication [50]. The ongoing development of new devices and applications is supported by continuous technological progress in the area of micro-electronics as well as an ongoing decrease in the prices of processors and memory. This trend was already identified by Gordon Moore in the mid-sixties and is today referred to as 'Moore's Law' [60]. In its original form Moore's Law states, that the complexity of integrated circuits doubles every year. In 1975 Moore corrected his initial estimate to a duplication of complexity every two years.

Today, Moore's Law is used in a slightly altered way expressing that the performance of computers doubles every 18 months, while size and price are decreasing [56]. Although Moore's Law is not a law in a scientific sense, its underlying assumption held true with an amazing precision and constancy over the last 30 years [56]. A similar development is also visible in the field of storage components. Over the last years storage capacity doubled approximately every two years, while prices are continuously dropping [57]. Moore's Law is expected to be valid for at least another 10 to 15 years, which means that computer processors and storage components will become much more powerful, smaller and cheaper in the future, so that there will be an almost unlimited supply of them (see, e.g., [7], [8] or [9]).

B. Current Technological Trends

Research in the area of information and communication technology is rapidly progressing, and a variety of new technologies are on the threshold to emerge. Some of these technologies have an immense potential to influence the design and functionality of future business technologies. Therefore, it is important to be aware of the basic principles of those technologies, in order to predict their impact on the design of future applications. The following sections give an overview over the most important research fields and briefly describe some new technologies that are expected to become reality within the next few years.

1) New Communication Technologies

Broadband wireless communication is one of the key technologies for most mobile work scenarios, and will enable office workers to access relevant information anytime and anyplace. Today, wireless internet access via WLAN or cellular phone networks is available at many locations and routinely used by most mobile workers. With technologies like Ultra Wide Band (UWB) or ZigBee, new communication modules become available, which require less energy and enable even faster wireless data transfer [56]. And the developments in the area of mobile networks are expected to continue with incredible speed. According to Gilder [31], the bandwidth of communication networks will triple each year for the next 25 years, while at the same time the cost per bit converges towards zero. While most wireless communication technologies are designed to transmit data over relatively long distances, for some applications much smaller communication distances are required. Especially to support close-up interaction between different persons or devices, transmission distances of a few centimeters up to one or two meters are totally sufficient. In this context, technologies like Near Field Communication (NFC) have a great potential to make the interaction between users and smart devices more intuitive by providing distance-sensitive interaction mechanisms [52]. Another emerging technology, that is especially useful when supporting interactions between different users, are Body Area Networks. Body Area Networks use the human body itself as a transmission medium for electrical signals of very low current, which enables, for example, that by touching a specific device an individual identification code would be transmitted, which could be used to personalize a device [48].

2) New Sensing Technologies

Using sensors to interface to the physical world is often cited as one of the most important challenges in computer science today [16]. Current technological advances in the field of micro-electro-mechanical systems enable the development of new types of sensors, which are significantly smaller than current sensors and consume less energy [85]. One of the main research goals is to use a network of interconnected sensors in order to continuously monitor environmental conditions. Those wireless sensor network consist of a multitude of spatially distributed autonomous devices, which are wirelessly connected with each other [73]. While the initial applications were mostly military-oriented, wireless sensor networks are today one of the underlying technologies for the development of smart space in different application areas [33]. Prototypes of sensor networks already exist [56] and first commercial products are likely to become available within the next years. The large-scale availability of wireless sensor networks will be inevitably accompanied by a paradigm shift in the usage of computers: while current systems mainly rely on manual user input, the next generation of computers will automatically capture physical events in real-time [16]. In addition, several new localization technologies

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are becoming available, that offer much higher location accuracy than currently available technologies do, both indoors and outdoors. Supplementing the Global Positioning System (GPS), Galileo is expected to be operational between 2008 and 2010 [58] and will provide even better positioning information than current GPS-based systems already do. Beside satellite-based navigation technologies, there are several attempts to use communication technologies like WLAN, GSM or UMTS for localization purposes. While the accuracy of those systems is not yet on the same level with GPS or Galileo, those systems have the advantage, that they still provide reliable location information while being indoors, which is currently still a problem with satellite-based systems.

3) New Interaction Technologies

Today, users interact with computers via special input and output devices. Most of these interfaces require the full attention of users and are therefore quite awkward to use in everyday situations. Current Ambient Intelligence research is addressing this problem by investing considerable effort into the development of new interface technologies. These technologies will enable users to directly interact with information and each other, thus making dedicated interaction devices obsolete. Previous evaluations (e.g., [72]) showed that especially gesture and speech interfaces are two technologies, which are favored by potential users. While first versions of speech and gesture interface are already implemented in commercially available phones and gaming consoles, the interaction possibilities are still quite restricted. While existing technologies only support a fixed set of input commands, future applications will enable an almost natural interaction between users and a smart environment.

Although speech and gesture interfaces bring a variety of advantages on the input side, using these technologies for output interactions is not always appropriate, especially in multi-user situations or public spaces. The most promising output devices for mobile Ambient Intelligence applications are probably Virtual Retinal Displays (VRD), which directly project the computer images onto the user's retina. Today, VRD-systems are mostly integrated in the frames of glasses, and project the computer image on a small prism in the glass, from where it is reflected onto the user's retina [53, 56]. VRD-systems are already successfully used in the automobile industry to support assembly and maintenance tasks. Studies at Honda show, that VRD-systems allow timesavings of up to 40%, which equals 2.000 Dollar of monthly labor savings per user [76].

4) New Materials

Recent developments in the area of material science enable a variety of new Ambient Intelligence applications. Smart materials will enable designers to build computers in a variety of new form factors and thereby contribute to the disappearance of technology into the background of attention. New display technologies like Organic (OLED) or Polymer Light-Emitting Diodes (PLED) have been successfully tested in prototypes and will become available for commercial products within the next years. In contrast to traditional LED technology, the substrate used for both types of diodes can be printed on different surfaces using inkjet printing methods. This does not only reduce the production costs compared to traditional display technologies, it also enables to transform a broad variety of everyday objects, including clothes and other personal accessories, into display surfaces.

Organic and polymer LEDs can serve as an underlying technology for a variety of Ambient Intelligence applications. Especially electronic paper has the potential to revolutionize the way people interact with digital information in work environments. By using paper-like plastic foils, users can display information and, in combination with a special pen, also use electronic paper as an input device [75]. First commercial products like 'Gyricon' or 'E-Ink' are already available.

C. Ambient Intelligence: Definition and Concept

Extrapolating the current development, we soon have to expect work environments, where computers are ubiquitously available in different forms and sizes. The increasing miniaturization of computer technology is expected to result in processors and sensors being integrated into more and more everyday objects, leading to the disappearance of traditional input and output media, such as keyboards, mice and screens [7, 8, 9]. This coming 'post-PC' era will be characterized by environments, where computers no longer primarily appear in form of a personal computer, and in which "a billion people are interacting with a million E-Businesses through a trillion interconnected intelligent devices" [54]. The recent developments in the mobile phone sector are often cited to be a forerunner in this new technological field. Today, smart phones are fully functional computers, equipped with a broad range of additional functionality, such as localization technology, internet connectivity and voice recognition [55].

This vision of a future, where people are surrounded by intelligent and intuitive interfaces embedded in their surrounding, is often described as 'Ambient Intelligence'. The concept of Ambient Intelligence (AmI) describes the integration of a variety of tiny micro-electronic processors and sensors into almost all everyday objects, which enables an environment to recognize and respond to the needs of users in an almost invisible way. The term Ambient Intelligence was coined within the European research community (see, e.g., [1] or [2]), as a reaction to the terms 'Ubiquitous Computing' and 'Pervasive Computing', which were introduced and frequently used by American researchers. In contrast to the more technical terms of ubiquitous and pervasive computing, Ambient Intelligence includes also aspects of Human Computer Interaction and Artificial Intelligence. Hence, the emphasis is usually on greater user-friendliness, more efficient services support, user-empowerment and support for human interactions [15].

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Ambient Intelligence applications are characterized by a high degree of embeddedness, using computers integrated into the physical environments in order to provide a variety of context-adapted user services. Over the years, a variety of terms emerged, which are often used synonymously with Ambient Intelligence. Almost all terms refer to the omnipresent support of users through computational devices embedded in the physical environment. Although some differences between the terms and concepts exist, most differentiations are of academic nature.

II. Ambient Intelligence in the Production and Retail Sector

While the concept of Ambient Intelligence was still formulated as a vision in the previous section, some of the underlying concepts are already integrated in business processes. Elementary forms of AmI technologies are already used to identify and track objects in the manufacturing process and the supply chain. Before some of those applications are described, the following sections briefly describe, how elementary business processes were changed by the usage of computers in the past.

A. Computerization of Business Processes

The introduction of Personal Computers into the workplace radically changed the way business processes are organized. Starting with the computerization of individual tasks, computerized data processing lead to the continuous integration of business processes in different areas. The development of integrated business processes in the 1990s was mostly achieved by consequent Business Process Engineering as well as Enterprise Resource Planning (ERP) systems [28]. The integration of business processes within individual companies was then extended by the coordination of processes between multiple companies in the supply chain. Following the current trends, the integration of real-world information seems to be the next logical step towards an even higher integration level in business processes [20].

The recent developments in the area of information and communication technology led to a variety of new services and business models. Table 4 gives a brief overview over some new terms and concepts.

Table 4: New business terms and concepts.

Term	Description
Electronic Business	The notion of 'Electronic Business' or 'e-Business' was first used by IBM in the 1990s as part of a promotion campaign and referred to the re-design of strategic business processes, based on the challenges of a new global market (see [80]). Over the years, the term was used in a variety of different and sometimes misleading ways. Today, most authors (e.g., Thome [91] or Herden and Zwanziger [34]) define the term 'Electronic Business' as the integrated execution of all computer-controllable business process, using information and communication technologies. E-Business applications include e-Commerce systems, e-Procurement systems, as well as digital marketplaces and portals.
Electronic Commerce	'Electronic Commerce' or 'e-Commerce' is a special form of an Electronic Business application, where electronic systems (primarily the internet) are used in order to market and sell products or services (for more details see, e.g., [44]).
Mobile Commerce	'Mobile Commerce' (also known as 'm-Commerce') is further a development of the original e-Commerce idea, where mobile devices, like smart phones or PDAs, are used to conduct commerce. Currently, the most prominent m-Commerce application in the consumer area is probably the sale of ring-tones and games for mobile phones. Business applications include for example the access of ERP systems using small mobile devices [5].
Silent Commerce	'Silent Commerce' or 's-Commerce' describes business transactions, which are autonomously carried out between machines or objects (machine-to-machine transactions), without any intervention by humans [54, 55]. Probably the best known example of a Silent Commerce application is the intelligent refrigerator, which automatically orders groceries over the internet. Business applications include automated repository systems, which autonomously order products based on previous sales data.
Ubiquitous Commerce	The term 'Ubiquitous Commerce' has to be seen as a combination of the previously described concepts of Electronic Commerce, Mobile Commerce, as well as Silent Commerce. According to Galanxhi-Janaqi and Fui-Hoon Nah [30] Ubiquitous Commerce extends traditional commerce to a world of ubiquitous networks and universal devices.
Real-Time Economy	The term 'Real-Time Economy' describes economic environments, where all entities in the economic process, such as goods, factories and vehicles, are enhanced with comprehensive methods of monitoring and information extraction [7, 9]. In an economical sense, this might result in an approximation of the perfect market, as information about the location and quality of goods as well as the means of production and people, is available in real time and an unprecedented accuracy [93]. The same concept is sometimes also referred to as 'Now-Economy' (see, e.g., [78] or [61]).

B. Today: Identification and Localization of Objects

The identification and localization of objects is probably the simplest form of an Ambient Intelligence application. This chapter presents several prototype applications, field tests and first successful examples of daily usage, and shows the benefits and potential of these applications in the business context.

1) Current Problems in Production and Retail

Many problems in the production and retail sector are caused by an insufficient integration of the real and digital world. In most cases, reality significantly differs from its digital counterpart, which serves as the basis for management decisions [27]. In an exemplary case, Raman et al. [68] showed, that the physical stock differed from the stock data in the corresponding database for over 30% of all items. Generally, between 5% and 10% of the demanded products are not available [6]. In the case of specially advertised products, only 85% of the articles are in stock [32], which leads to a drop in sales of approximately 3% to

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4% [37]. In addition, each year theft, fraud and administrative errors in the American retail sector lead to a stock shrinkage equivalent to 33 billion USD [36]. Similar numbers are reported from Europe, where according to ECR (Efficient Consumer Response), retailers loose about 1,75% of their sales because of shrinkage [85].

2) Potential of Ambient Intelligence Technologies

Ambient Intelligence technologies can help to support the integration of the digital and the physical world by seamlessly connecting real-world objects with their digital representations in information systems [20]. Today, media breaks are one of the main factors for the limited efficiency of many business processes [21], and occur in different stages of the supply chain. A prominent example for a media break are recurring order entries in subsequent steps of the value chain (see, e.g., [28]). By automating these processes, less human intervention is required and laborious manual data gathering is avoided, which in turn leads to reduced costs and thereby improves overall efficiency [75]. Hence, preventing such media breaks is the key to efficient business processes.

3) Key Technologies and Pilot Projects

Radio Frequency Identification (RFID) if often cited as the key technology for integrating the physical and the virtual domain, by bridging the gap between the physical reality of a company and its information-technological representation [10]. By attaching RFID transponders to physical resources, they become smart in a way, that they can communicate automatically with the information systems of the company [21]. Until today, most prototype applications and pilot installation using RFID technology were done in the automobile, logistics and transport industries. More recent application examples come from life sciences and the retail sector [54, 55]. Table 5 gives an overview over existing industry applications, which are using RFID technology for tracking and identification.

TABLE 5: OVERVIEW OVER INDUSTRY APPLICATIONS USING RFID TECHNOLOGY.

Company	Application
Gillette & Tesco	The British supermarket chain Tesco was one of the first companies that was experimenting with RFID labels on product level. In a pilot test smart shelves and tagged products were used to increase product availability and reduce theft. The test installation included a security mechanism that activated surveillance cameras and notified store personnel, as soon as more than three packages of tagged Gillette razor blades were taken from a smart shelf [42].
Prada	The designer label Prada made tests with an RFID-based sales and promotion application in its flagship store, in order to increase the shopping experience and customer consultation. But the results were rather disappointing: neither customer service nor stock management could not be improved [70]. Nevertheless, the experienced problems were not of technical nature, instead, insufficient integration of the test application into internal business processes caused the bad result [69].
The Gap	The clothing chain The Gap conducted field studies, where Jeans were tagged with RFID transponders [88]. After the three months test period it could be shown, that the efficiency of the supply chain and costumer support was improved and that product availability was increased to nearly 100%.
Metro Group	The German Metro Group cooperates within the Metro Group Future Store Initiative with over 50 companies, both from industry and research. In the specifically designed Metro Future Store, RFID-based technologies are tested under real-world situations. The focus of the field tests is mainly on the usage of RFID technology in the supply chain.
Sainsbury	The British retailer Sainsbury uses RFID technology to track chilled food products from the receiving, through distribution, to the store shelf (see, e.g., [75], [85] or [95]). A pilot test with re-useable transport containers [39] proved additional shelf life time and better replenishment planning. Compared to the previous barcode-based system, check-in and check-out activities could be speeded from 2.5 hours to half an hour [23, 24].
Nortel Networks	Nortel Networks developed an RFID-based local positioning solution in order to avoid searching expensive test equipment, which needs to be accessed by many engineers. Since the introduction of the system most devices could be found in less than five minutes [40].
Volkswagen AG	The Volkswagen AG uses RFID-based tracking systems to identify cars during the delivery process [38] and to manage spare parts [11]. Field tests with loading carriers showed a reduction of circulation time by 5%, a reduction of carrier loss by 3%, a reduction of search time by 75%, and a reduction of idle time in the production process by 35% [66].
Ford	Ford implemented an RFID-based system called 'WhereCall' in order to increase reliance of parts supply [63]. The 'WhereCall' system is also connected to Ford's e-Smart system, which automatically sends out orders to the corresponding supplier, if the inventory falls below a predefined level [75, 85]. Ford has already implemented this solution in 25 plants and thereby significantly reduced material outages and inventory levels [23, 24].
Infineon	The German microchip manufacturer Infineon uses RFID-based temperature loggers to monitor temperature-sensitive chemicals during international transport processes. Sensors attached to the transport units perform continuous measurements and provide the temperature history via an infrared interface using a portable computer [75, 85].

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Scottish Courage	To counteract their 3% to 5 % shrinkage of aluminum kegs per year, the brewery Scottish Courage implemented an RFID-based system to individually identify their kegs and to track to what customers they are lend out, which enabled the brewery to get their asset back or claim for refund [40].
Exxon Mobil	Since 1997, Exxon Mobil uses an automatic billing system called 'Speedpass' (see, e.g., [18]). By bringing an RFID-enhanced watch or key-pendant close to the gasoline pump, the paying process is automatically triggered. Since the introduction of the system Exxon [17] reports, that 92% of all Speedpass users are very satisfied with the Speedpass system, and that Speedpass was used for payment in 18% of all transactions. In the same period, the petrol sales rose by 15% at many filling stations, and the sales within the shops could be increased by 4%.
Pacific Century Systems	The Hongkong-based telecommunication company Pacific Century Systems uses an RFID-based tracking system to localize tagged office objects in real-time. Employees can access the positions of all tagged objects via their mobile phone or desktop computer. In addition, Pacific Century Systems uses the collected data to gain more information about the usage of their office resources. For more information on this system, see, e.g., [26].
U.S. Postal Service	In 1999, U.S. Postal Service and Motorola were among the first companies that used RFID technology in a large-scale pilot project [22, 25]. Within the project 'Surface 2000', RFID transponders were attached to packets in order to automatically track them while loading and un-loading delivery vans. Today this technology is used by almost all international parcel services, like UPS or FedEx [5] and significantly reduces the number of lost and misrouted packages.
Campofrio	The Spanish food producer Campofrio uses RFID technology in order to reduce manual data input during the production process. Microchips attached to gammon are used to control the aging process and continuously capture relevant data like weight, temperature and water content [26].

A variety of other companies, including Kaufhaus AG in cooperation with Gerry Weber International [87], Marks & Spencer [12] and Benetton [71] conducted internal field studies with RFID-based systems. Further examples for RFID-based applications and prototype testing in different industry fields can be found in [35].

4) Conclusion

In general, the cases listed above show, that the integration of the real and the virtual world by means of RFID technology has the potential to enable various cost-saving and revenue-generating benefits [20]. A variety of pilot projects (see Table 5) showed quite promising results in the areas of production and stockkeeping as well as for SCM applications. But using the same technologies in the retail sector led to considerable protest from users (see Table 6). The following paragraphs briefly outline the results of field studies in different domains and elaborate the differences that contributed to the results.

Current application scenarios are mainly based on automatic identification and localization of objects [85], and thereby significantly reduce media breaks by automating data input. According to Fleisch [19], this is the basis of two major business benefits. First, automation speeds up processes by reducing the dependency on humans, who can only process information sequentially but not in parallel. And second, automation also reduces processing error rates which are, at least when applied to standard tasks, much lower for computers than for humans. This in turn leads to several, more specific benefits in the area of production and stockkeeping. For example, automatic identification processes increase efficiency in goods receipt and issue, as no manual data collection is necessary [87]. It also enables efficient tracing of physical consignment, which helps to detect differences between planned and actual status of consignment in an early stage [65]. Similar results were found in pilot installations by Identec Solutions, where efficient tracking of load carriers based on RFID technology could reduce the required amount of carriers between 5% and 20% [81]. In addition, real-time status information enables manufactures to react to changes in the delivery process in time and adapt the production process in order to avoid machine idle times.

Today, the majority of RFID-based applications in the manufacturing industry is only used within one company. At the same time, up to 25% of the running costs in the manufacturing industry fall to supply chain management [59]. Using the same tracking and tracing mechanisms along the supply chain is likely to lead to a considerable efficiency increase in SCM through the avoidance of errors, the reduction manual data input, and the decrease in processing times [84]. In addition, Lee et al. [45] argue, that the usage of RFID-based systems by all companies along a supply chain, will not only contribute to more precise inventory data and real-time order information, but will also lead to additional savings by attenuating the 'bullwhip effect'. Hence, several authors, e.g. Fleisch [20], assume that business systems based on Ambient Intelligence technology have the potential to initiate a new wave of business process redesign, similar to what ERP and e-business systems did in the past.

In current production and SCM applications, RFID technology is usually used on container level, which is sufficient for most usage scenarios. In the future, falling transponder prices will enable tagging on product level, which is especially interesting in the retail sector. Benefits for retailers range from simplified sales and cashing procedure due to self check-out applications to automated store inventory using smart shelves. But the usage of RFID in the retail sector might also lead to privacy violations, if RFID transponders are not removed after the completion of the sales process or if they are used to monitor customer behavior inside the store. For example, the plan of Tesco

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and Wal-Mart to use RFID technology on product level raised serious concerns from consumer protection lobbyist.

Currently, several pressure groups are fighting against the usage of RFID in the end-consumer market. The most active are CASPIAN Consumer Advocacy (Consumers Against Supermarket Privacy Invasion and Numbering) in the USA, and FoeBuD (Verein zur Förderung des öffentlichen bewegten und unbewegten Datenverkehrs e.V.) in Germany. The following table documents the conflicts between these two groups and companies that employed RFID in retail.

TABLE 6: OVERVIEW OVER CONFLICTS BETWEEN PRESSURE GROUPS AND COMPANIES THAT EMPLOYED RFID IN RETAIL (SEE [89]).

Company	Incident
Benetton / Philips	*March 11, 2003:* Benetton announces plans to sew in RFID transponders into Sisley textiles. Two days later, CASPIAN calls on a boycott of Benetton products over the internet.
	April 9, 2003: Benetton publishes a press report announcing that they refrain from using RFID in textiles.
Wal-Mart / Gillette	*July 8, 2003:* CASPIAN publishes 68 confidential reports of the Auto-ID center, which is mainly sponsored by Wal-Mart and Gillette. Two month before, Wal-Mart started an RFID pilot project for automated inventory in sales rooms.
	July 9, 2003: Wall-Mart stops the pilot project and announces that from now on RFID will only be used in internal stocktaking.
Tesco / Gillette	*July 22, 2003:* Tesco is accused to use a combination of RFID and surveillance cameras in order to detect and photograph costumers while taking razor blades out of the shelves.
	August 15, 2003: Gillette denies all accusations, while Tesco admits to have tested "security-relevant advantages" of RFID technology. The tests were stopped end of July.
Metro	*February 1, 2004:* FoeBuD demonstrates in front of the Metro Future Store against the usage of RFID-based customer cards.
	February 27, 2004: Metro exchanges 10.000 customer cards for cards without RFID chips.

C. Tomorrow: Smart Products and Services

The last section gave an overview over the first generation of smart business applications. Some of these applications are in everyday usage for several years now, and within this time period proved to be rather successful. Nevertheless, 'smart' applications based on location and identification information, provided by RFID systems, are only the beginning of fundamentally new forms of smart business applications. Within the next years, interconnected smart objects will provide context information, which go far beyond traditional location information, and thereby enable a variety of smart services. The following sections provide an overview over new concepts, ongoing work as well as research prototypes in this field.

1) Smart Products

Today, micro-processors are integrated into almost all high-tech products, ranging from household appliances to automobiles. Already in 2000, over 98% of all 8 billion produced micro-processors were embedded in devices other than computers [51]. And this trend is likely to continue in the future. With information and communication technology becoming even smaller and cheaper, computers are likely to be integrated into almost all objects of everyday life. Hence, a variety of authors, e.g., Mattern [49, 56], expect future products to be hybrid goods, which consist of a physical part (e.g., a drug with its biochemical and medical effects) as well as a digital part (in case of medicine, for example, additional up-to-date information about the chronological sequence of an influenza epidemic).

Similar to smart artifacts, such 'smart products' describe technology-enhanced goods, which are able to communicate and interact with their surrounding. Some authors, e.g., Fleisch et al. [22], also refer to smart products as 'hybrid products', as they combine physical and digital elements within one object. In this sense, traditional products equipped with RFID transponders can, to a certain degree, be called 'smart', as they have the potential to trigger other functions within smart environments, and thereby initiate far reaching changes in the physical as well as the digital world [93].

Over the last couple of years, first research prototypes of business applications using smart objects have been developed. Most of these applications dealt with the management of moveable assets in production or service environments. The goal of these applications was to make assets, like vehicles, containers or tools available when needed and ensure their efficient use [40]. Table 7 shows two examples for tool management in the aircraft industry.

TABLE 7: APPLICATIONS FOR TOOL MANAGEMENT IN AIRCRAFT MAINTENANCE.

Application	Description
Smart Toolbox	The smart toolbox [29, 83] is a technology-enhanced physical toolbox, which is able to identify tools and log their usage in order to calculate the condition of each tool. Based on this information mechanics can be notified of missing, missorted or worn tools. The smart toolbox works autonomously, but is able to wirelessly send and receive data from other applications, like, e.g., the company's tool management system [40].
Smart Tool Inventory	The Smart Tool Inventory [40, 82] is an RFID-based inventory and check-out system for special tools in the aircraft maintenance sector. Based on RFID transponders attached to the tools, a smart check-out counter is able to uniquely identify each tool that is put on the counter for check-out. This information is combined with data read from a smart security badge of the mechanic, who is checking out the tool.

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Other examples of smart products are smart machines, which are equipped with sensors and actuators and are able to communicate with their surrounding. Today, most applications of smart machines are machine-to-machine (M2M) applications, where a smart machine directly communicates with other smart devices or a central application. Those M2M applications do not require any action from the outside, like manual data input by workers. The captured data are usually stored and controlled by a central entity, like an enterprise resource planning (ERP) system. For example, Canon offers a so-called 'Remote Diagnostics Systems' for their copying machines, which informs the support center about operation failures and automatically orders new toner cartridges if necessary [86]. Other examples of smart products include smart books [90] or smart car tires, which send the driver a message when it looses pressure [20].

2) Smart Service

Smart Products do not only have the potential to make existing processes more efficient, they also offer a variety of possibilties for designing new products and services [75]. These so-called 'smart services' include, for example, dynamic pricing mechanisms and pay-per-use applications. While traditional electronic services, like e-Payment, e-Fulfillment or e-Logistics, support clearly defined functions [26], smart services enable the integration of the physical reality into various types of business applications [20].

a) Dynamic Pricing

If products are equipped with sensing, computing, and communication capabilities, they are not only aware of their own state, but also have knowledge about other products or costumers in their vicinity [43]. This knowledge can be used, for example, by customer relationship systems to generate more detailed and accurate sales pattern and costumer profiles [78]. Such information would allow companies to conduct buyer-specific one-to-one marketing with immense cross-selling potential, which goes far beyond current marketing mechanisms, based on information from target groups (see [67]). In addition, personalized price discrimination would become possible. This would enable retailers to quote an individual price for each consumer, which exactly corresponds to his readiness to pay (see, e.g., [64] or [79]). If additional environmental parameters would be included into the pricing mechanism, it became possible to adapt the price not only to a specific customer, but also to the current situation. So, for example, when the outside temperature rises, soft drinks and ice cream could increase their prices according to the expected increase of demand [43].

Although dynamic pricing mechanisms bring a variety of advantages for retailers, it is not yet clear, if customers will accept individual prices or not [49]. Already in 2000, the online-bookseller Amazon conducted a field study with individual DVD prices, but had to suspend the trial after only two weeks due to massive criticism from customers [78, 92]. Although Amazon refunded the price difference to all customers, who had bought DVDs during this period, the company's image was considerably damaged by this campaign [14].

b) Pay-Per-Use Applications

Another example for smart services are pay-per-use applications. Traditionally, pay-per-use payment models were mostly used for public utilities (like gas, electricity or water) and, until recently, also in the telecommunications industry. In the future, smart products equipped with sensors and communications capabilities, will enable new billing and leasing models, based on the actual usage of the object [27], which guarantees, that customers only pay for what they use. In addition, pay-per-use models could also become a valuable political tool for steering developments, like, for example, the reduction of traffic through a mileage- and time-based consumption tax [43]. Nevertheless, it depends on the acceptance of customers, whether pay-per-use models could be successfully implemented or not. Especially after the change to flat-rate models in many areas it seems, as if users prefer the freedom that flat rates buy them over traditional billing schemes. But if consumers were to accept pay-per-use applications, this would not only lead to a permanent surveillance of their personal habits, but it would also enable companies to exercise control over the use of their products and services [43]. Hence, it is very likely, that dynamic paying mechanics will be only successful in certain domains or for certain services.

c) Dynamic Insurance Policies

Nowadays, insurance companies have only limited information about their customers and the goods they insure [43]. Typically, the insured assets are split into classes, based on a few criteria, which are collected before the risk coverage starts [61]. For example, car insurance premiums usually depend only on the type of the insured car, the experience of the driver and sometimes also on the type of location the car is usually parked, even though the real risk of having a traffic accident depends on a variety of additional factors: such as the driven mileage, traffic and weather conditions as well as when and where the car has actually been driven or parked [43]. Ambient Intelligence technologies, embedded into the insured goods, could provide very detailed information about the actual usage of the goods. This data could then be used to calculate more accurate insurance premiums, based on the risk involved for the insurer. A smart car, for example, could provide detailed information about the driving style and parking habits of its owner, thus providing the insurer with a much better assessment of the likelihood of an accident or theft [7, 9]. Especially in the area of car insurance, several companies have started exploring the possibilities current AmI technologies offer in order to calculate dynamic insurance rates [43]. Table 8 gives two examples of pilot projects where tracking technologies were used in order to provide individualized insurance premiums.

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TABLE 8: PILOT PROJECTS OF DYNAMIC PRICING MODELS IN THE CAR INSURANCE INDUSTRY.

Company	Description of Pilot Test
Progressive	Already in 1999 the American insurance company Progressive conducted a pilot project with a dynamic insurance policy for cars in Texas [5]. Using a satellite-based location system, all rides were continuously tracked. At the end of the billing period, the insurance premium was calculated, based on the actual usage of the car.
Norwich Union	A similar system called 'Pay As You Drive' was implemented by the British insurer Norwich Union. The system calculated the monthly insurance premiums, based on how often, when and where the car was used [47]. The necessary data was collected by GPS system installed in the car and transmitted through a mobile communication unit directly to the insurance company.

User studies with such dynamic pricing models in the insurance industry showed quite promising results [42]. For a reduction of the insurance premium by 25%, many customers were willing to accept tracking devices in their cars, which continuously transmitted their current location to the insurance company [53]. The same tracking technology is currently also being tested in the rental car sector, to ensure careful usage of rented vehicles. An American rental car company, for example, charges a premium for dangerous driving, if the car is driven with more than 79 miles per hour [46]. Similar pricing models are possible in other insurance fields, too. For example in a household insurance, new furniture could automatically register its net worth when placed inside the home, or in a health insurance, smoking would increase the rate, a walk in the park decrease it [7, 9]. In addition, 'day-by-day insurance' would become possible, where customers could change their insurance rate or company on a regular basis. Similar to least-cost-routers in the telecommunication industry, smart goods could autonomously choose the most favorable insurance company for that day [43].

The examples show, that dynamic insurance policies have the potential to generate significant savings for consumers, and thereby possibly prompting a large enough market share to convert from traditional, fixed-rate insurance policies [43]. Especially for low-risk customers, significantly reduced rates might be very welcome, even if they have to give up some of their privacy [13]. And as low-risk customers are likely to change to dynamic models, those, sticking with traditional models would need to pay a higher premium, as the overall risk of the remaining class would consequently rise [43]. Over time this would naturally result in fair insurance premiums for each customer, based on the actual risk involved for the insurance company.

Even if insurance customers are already used to personalized and periodically changing insurance premiums, based for example on age and driving experience, such new pricing models will go far beyond what is currently possible. This in turn will give rise to a range of new problems and concerns, like, for example, a potential loss of transparency, especially if the underlying assessment methods dynamically change, or if they were unknown or too complicated to be understood by the user [9]. In addition, freedom of choice could be threatened, as customers, who do not wish to provide their details to their insurance company, would most likely have to pay a considerably higher premium, as the insurer's risk would be spread among fewer and fewer non-participating customers [7]. In the long run, such developments might lead to a fine-grained surveillance network, where the classic legal assumption of innocence is inverted into a principal assumption of guilt, and people, who are not able to provide a recording of the incident, are automatically suspicious [41].

Finally, smart products might also contribute to reducing information asymmetries (see [3]), and thereby revolutionize trading at a very fundamental level. By increasing the overall market transparency, both for new and used goods, smart products and services have the potential to increase overall market activities by reducing the uncertainty inherent in many transactions today [7]. In this context, Bohn et al. [9] provide several examples of smart goods, which could not only 'talk' about their price, ingredients and availability, but can also provide a detailed history of their production, use and repair. According to their vision, a used smart car could give a detailed list of the parts that have been replaced or repaired over the course of its lifetime, thus reducing the amount of trust the buyer must have in the seller. In the same way, organic food could provide potential buyers with a comprehensive history of its cultivation, fertilization and processing, and thereby increase the willingness of customers to pay a premium for it.

III. SUMMARY AND OUTLOOK

A variety of authors, e.g. Fleisch et al. [27], consider Ambient Intelligence applications to be the next logical step in the design of future business systems. Already today, many companies employ first versions of AmI technologies in order identify and track objects, which provide them with real-time data about their assets, and thereby enable them to immediately react to changing situations [78]. By reducing process costs and business risks, and consequently enhancing sales and business opportunities, smart objects and services have the potential to lead to lasting changes in the design of current business processes [20, 75]. Over time, the availability of information anywhere, anytime and about anything might not only make today's businesses more efficient, reliable and customer-friendly, but could also stimulate the transformation of existing business processes and the emergence of entirely new business models [43].

Nevertheless, the increasing automation of economically relevant aspects and the exclusion of humans as decision makers could certainly become a cause for concern [7]. While computer-controlled processes can decrease the error rate in routine tasks, situations, that have not been anticipated in the design of the software, can easily have disastrous consequences, if they are not directly controlled by humans [8]. The best-known example in the business

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context is probably the stock market crash of 1987, which was partly caused by inappropriately implemented trading software (see, e.g., [78]). And last but not least, the acceptance of the presented technologies through employees strongly depends on whether companies can convince potential users of the advantages in daily usage [87].

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