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DRAFT

Wearable Computing in Industrial Service Applications

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Abstract

Wearable computing promises to gain efficiency improvements in industrial applications due to augmentation of the device as well as improved interaction between the user and the device. In this paper, we present the results of a study with focus on utilization of wearable computing in industrial service applications. Our study consisted of a preliminary market scan with regard to wearable computing devices and literature analysis that has been conducted to find out where wearable computing is already used or is well suited for industrial service applications.

Keywords: wearable computing, ambient systems, industrial service applications

1. Introduction

Today, industrial service requires appropriate information for a service case, such as handbooks, how-to's, bestpractices, decision trees, error-codes etc. The data is slowly processed, e.g., due to time consuming media conversion and paper work. Service engineers are well trained for the particular product or system area. In complex service cases, beside the well-trained topics, additional information, such as best practices and supporting software tools are required to solve actual problems at a site. Especially during site audits information must be collected to outline the current state of the installed equipment. In addition for full service or safety audits a set of tools is used to calculate and outline how the plant health and safety could be improved and guaranteed. Hereby, service experts must be physically present at a site.

When a customer identifies need for a service, it is difficult for him to describe the current case. The service providing company needs information about the installed faulty equipment and potential error codes to give the customer a first hint about a potential solution for the current case. Quite often service engineers are demanded at a site for trivial cases due to a lack of information.

Wearable computing may provide a considerable impact on the aforementioned industrial service areas. Many of the proposed solutions designed for the healthcare domain (for example [14] and [15]) and military domain (e.g., [24]) have similarities that let us expect successful application of wearable computing to industrial services. Although wearable computing looked like making a breakthrough in the industry almost a decade ago [20], device costs today are still a serious obstacle for wide-spread applications. As the healthcare domain has great demand for safety and the military pursues effectiveness and tactical advantages, typical industrial service organizations cannot afford all the latest gadgets without certainty of return of investment. It is difficult to motivate for example a manager of process

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automation service to invest 4000 dollars in an head-mounted display (HMD) for each of his 2000 field technicians if there is a risk of not improving the overall efficiency in the organization which might be due to poor ergonomy, technical problems and the general practicality. The price class of a smart phone is expected to be a good approximation of acceptable costs in comparison to the risk. In 2011, industrial services require well demonstrated and proven solutions that are yet to be investigated.

This document presents the results of a preliminary market scan regarding wearable computing devices and literature analysis that has been carried out to identify potential application scenarios and use cases for industrial service applications. We compared the approximate costs and technical capabilities of the devices to practical use cases presented in other studies and discuss practicality and near-future prospects of wearable computing applications for industrial services.

2. Wearable Computing Devices – State of the Art

In the initial phase of our study, we evaluated existing commercial wearable computing devices that might be suitable for industrial service process improvement. We considered technical capabilities as well as price. In the following, we summarize conclusions for each category of devices and present representative examples:

• Output devices

Head mounted display (HMD) market survey by Sensics in 2008 [3] shows that the “good enough” HMDs do not yet exist. The situation in 2011 is not essentially better. Todays commercially available HMD-based output devices are bulky and ergonomically questionable for wide scale industrial applications. Some recent products, such as i-glasses 920HR are getting near to the price and practicality that would enable industrial applications. High-quality products that are both practical and ergonomic, e.g., designed for military use, are still very expensive and thus cannot be considered for cost-oriented industries. Next-generation OLED microdisplays and retinal displays are expected to solve practicality issues in the next few years. Some of these latest technologies that have been demonstrated in fairs and conferences, such as AR Walker from NTT DoCoMo and TeleScouter from NEC set expectations high for the next wave of HMDs. However, today’s practical low-cost applications of a few hundred dollars can be built on wrist-worn conventional TFT-LCD displays, such as IDView’s IV-2535D wearable monitor.

• Wearable video cameras and eye/head-trackers

Advances in video camera technology has lead to low-cost wearable video cameras that provide acceptable level of resolution and framerate. For example, You-Vision offers video glasses of 640x480 pixel recording at 25 fps at a price of 150 dollars. Looxcie offers a somewhat similar product. Wrap 920AR from Vuzix combines a near-eye 2D/3D video see-through display and video recording into an eye-glass frame which also has gyro and acceleration sensors to enable head tracking, offered at a package price of about 2000 dollars. Wearable video cameras today are robust and available for reasonable price, but battery life may still limit the usage in practice. Tobiiglasses provide a comprehensive solution including eye-tracking capabilities and an analysis software at a package price of 45000 dollars. Video cameras equipped with eye-tracking are expensive, which at this moment seem to be due to lack of competition, but with mere head-tracking features they are close to affordable. Only plain video cameras are cheap.

• Input and sensing devices

Wrist-worn keyboards such as WristPC from L3 Systems or FrogPad intended for portable computer use are practical options in the price class of a few hundred dollars. They, however, are not exactly wearable since they are intended as extension to mobile phones and such consumer electronic devices. Data gloves are still rather expensive; for instance PINCH Gloves from Fakespace Labs and CyberGlove II Wireless from METAmotion cost several thousands of dollars and they have so far been utilized in rather stationary virtual reality platforms and such experimental environments. Full body motion tracking is in the price class of tens of thousands of dollars and is strictly limited to lab use. Cheap input devices can be made by attaching latest gyro, acceleration and inertia sensors, e.g. B-Pack WAA006, to arms at a less than 500 dollars, but such interfaces will have very limited and non-standardized operability by the user compared to wrist-worn keyboards.

• Wearable PCs

Wrist-worn PCs, such as W200 from Glacier Computer, offer Windows-style interaction with a full computer, which however is far from wearable computing ideals. Head-mounted computer concept demonstrated e.g. Golden-i from Motorola, is a promising and technically capable approach, since the whole PC is mounted on the user with voice recognition and head tracking input and LCD display output. This sort of comprehensive platforms can be expected to be released to markets soon and boost the wearable computing applications, if the price can be kept around conventional laptop computer prices.

3. Wearable Computing in Industrial Applications

In a second step, we conducted a literature analysis. We used the Scopus database (http://www.scopus.com/) for an initial investigation with regard to the utilization of wearable computing devices in industrial applications. We submitted several queries for this purpose (cf. table 1 and figure 1).

Table 1: Scopus Results Regarding Publications Related to Wearable Computing

Year	Query 1[1]	Query 2[2]	Query 3[3]	Query 4[4]	Query 5[5]	Query 6[6]
1995	1					
1996	4					
1997	12					
1998	6					
1999	11				1	
2000	19	1				
2001	22	1				
2002	24					1
2003	41	2	2	3		2
2004	57	2		1		
2005	48					
2006	48	2	2	2		
2007	90	9	4	5		1
2008	77	4	2	2		1
2009	67	4		1		1
2010	67	4				3

[1]TITLE-ABS-KEY(“wearable computing”)
[2]TITLE-ABS-KEY(“wearable computing” AND (“industrial application” OR “case study”))
[3]TITLE-ABS-KEY((“wearable computing” AND (“aerospace” OR “avionics” OR “aircraft maintenance” OR “aircraft assembly”))
[4]TITLE-ABS-KEY((“wearable computing” AND (“aerospace” OR “avionics” OR “aircraft”)))
[5]TITLE-ABS-KEY((“wearable computing” AND (“factory automation” OR “plant automation”)))
[6]TITLE-ABS-KEY(“wearable computing” AND (“car manufacturing” OR “automotive”))

Based on the results obtained, we took a closer look at the literature. Therefore, we also considered Scholar Google (http://scholar.google.de/) to seek after additional publications.

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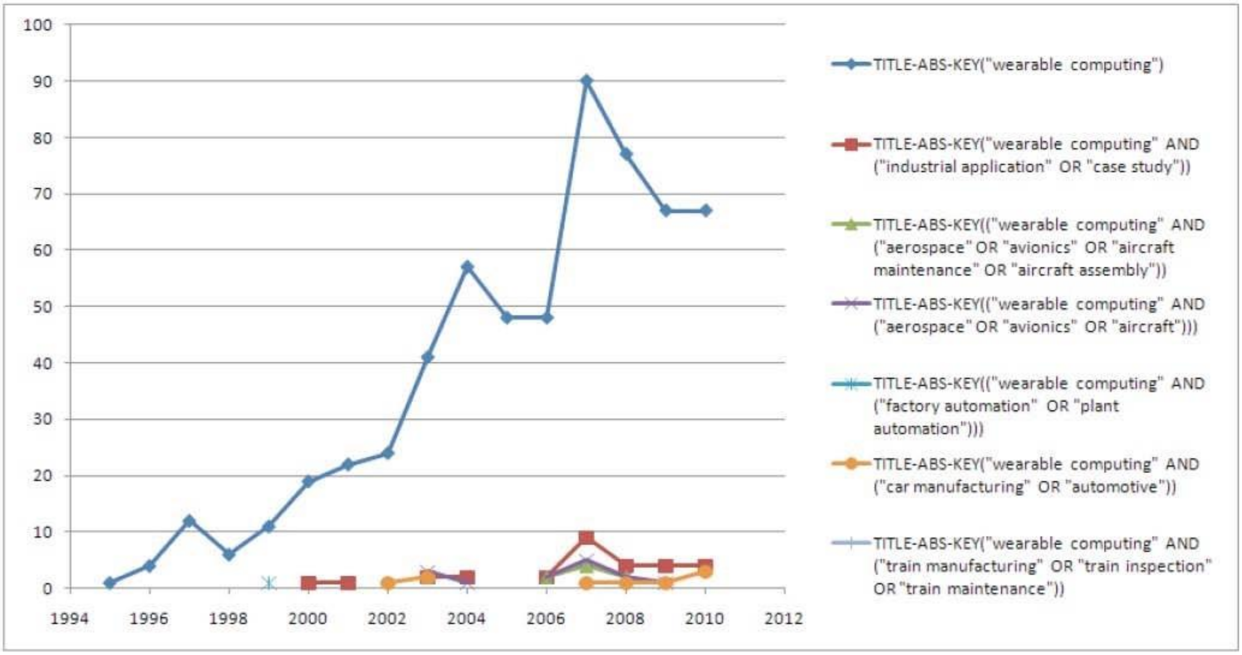

Figure 1: Regarding Publications Related to Wearable Computing

• Maintenance

Nicolai et al. [12] present an approach for a combination of wearable computing and knowledge management which aims at shortening the maintenance process in the aircraft industry. The authors identify functionalities such as logbook and self-diagnosis overview, accessing detailed defect reports, accessing manuals, location list, accessing similar defect reports, navigation through error classification, expert contact information, and writing repair reports in order to support the technician with relevant information and documentation. A combination of wearable computing and knowledge management for shortening the maintenance process in the aircraft industry is described in [13]. The authors present the results of user interviews which emphasize the identification of required maintenance, finding task related documents, and documenting the work as subtasks which can be improved utilizing wearable devices. Siewiorek et al. [19] describe a next generation train maintenance and diagnosis system that utilizes mobile information and communication technologies. The presented prototype enables maintenance personnel at the site to communicate with a remote helpdesk / expertise center through digital data, audio, and image, thus supporting preventive maintenance activities and handling of unusual faults. Baudhuin [2] describes the concept of providing military maintenance personnel with a wearable computer and interactive electronic manuals to support maintenance tasks.

• Quality assurance inspections

Najjar et al. [11] describe a wearable voice-operated computer for quality assurance inspectors in a food processing plant.

• Activity tracking

A context-aware wearable computing system supporting production or maintenance worker in automotive industry by recognizing the worker's actions and delivering just-in-time information about activities to be performed is introduced in [22]. • Collaboration between user pairs

Siegel et al. [18] present an empirical study of aircraft maintenance workers. In computer supported cooperative work, wearable computers have often been utilized to aid service technicians in a certain task.

• Wearable communities / social networks

Kortuem and Segall [9] discuss the social potential of wearable computers (wearable communities) and introduce general design principles for such communities.

• Proactive instructions (for furniture assembly)

A framework for proactive assembly instructions which aims to overcome the limitations of today's printed and computer-based instructions is proposed in [1]. The suggested approach is based on attaching several computing devices and multiple sensors onto different parts of the assembly, thus the system can recognize the actions of the user and determine the current state of the assembly.

• Hands-free documentation

Ward and Novick [23] introduce a general analysis of the requirements and design choices for hands-free documentation including the corresponding roles and characteristics of input and output modalities such as speech.

• Opportunistic sensing

An introduction to opportunistic sensing is provided in [16]. The described technique allows collecting information about the physical world and the persons behaving in it.

• Mobile E-meetings (e.g., electricians working at remote installations)

Drugge [6] explores the support for mobile e-meetings through wearable computing. The analyzed aspects include topics such as how mobile e-meetings can be supported by wearable computing.

Additionally, Bürgy [4] provides a compilation of projects with focus on wearable computing & augmented reality. The described use cases include support for vehicle inspections, end-of-line inspections in manufacturing, bridge inspections, crane operator assistance, and inspection of manufacturing machinery. Unfortunately, there is almost no information with regard to the successful application in industry. Stein et al. [21] report about commercially successful wearable device utilized by United Parcel Service. The economics of wearable computing is another topic that needs further investigation. Besides a few articles and case studies reporting of working time improvement of 50% [5] or even 70% [7], little is known about the real impact of wearable computing on industrial working environment, thus making further research necessary.

4. Discussion

As the survey to literature and state-of-the-art devices shows, wearable computing solutions on one hand show high potential for improving industrial services, but on the other hand they seem to lack solid foundation in implementation techniques and methods as well as in demonstratable profitability. Some of the main limitations for widescale industrial deployment in 2011 are:

• Infrastructure

Major limitation is set by non-existing infrastructure. Since the only functioning and widely deployed infrastructure is based on 3G network, smartphones and their extensions, such as Apple's iPhone and App Store, true wearable computing applications need something similar as a deployment platform. A more flexible and easily extendable platform would enable more companies to explore the true potential of wearable computing. Internet services such as Twitter are becoming more and more interesting for experimental infrastructures, but have limitations in acceptance in the industry unless deployed as private, closed networks.

• Reliability

Because of the lack of infrastructure, reliability is an uncertainty that does not encourage industrial service companies to invest in wearable computing projects. Industrial standards for technology as well as operations require steady, error-tolerant infrastructure which service workers could depend on. The only reliable services available today enable phone calls and 3G data transmissions.

• Complexity

The complexity of today's wearable and ubiquitous applications requires additional approaches to facilitate the development of such applications in a time- and cost-saving way. This includes the ability to invisibility and fusion management, seamless integration of ubiquitous wireless networking and sensing technologies as well as management of context information to address the complexity of such applications. Although, the complexity aspect had already been identified by Kortuem in 1996 [8] as a critical factor in the development of wearable computer, there is still a lack of a comprehensive solution and tool support addressing this challenge.

• Cost

Devices that can be considered for simple applications are plenty and many types of devices are now becoming affordable for widescale deployment. Unfortunately each application is case-specific which is seen in the industry mainly as a risky investment because convincing case studies are still few. Commercially available platforms that could be classified as wearable computing may emerge soon in the consumer domain, but few of the developments in this direction can be expected to be applicable directly for industrial services. Currently only certain industries can afford applied science experimentation whereas others require proven cost-benefit calculations before making investment decisions.

In short, in order to make a breakthrough in wearable computing in industrial service industries, applied science sector has to produce more case studies of reference system prototypes and device manufacturers need to enhance functionality without raising costs. Moreover, crucial infrastructure has to be built from IT service point of view in order to meet the requirement for reliability.

5. Conclusions

Wearable computing is an innovative technology which is now beginning to enter markets such as for military applications and consumer goods, but also for industrial products and services. Technological maturity is getting close to a state where real industrial applications can be realized, providing a source for competitive advantage to pioneer companies. Currently, the price for full scale wearable computing including HMD-based augmented reality and hand gesture based interaction is rather high, but low-cost simple applications are well within reasonable budgets for use cases that do not require much conscious input from the user. However, widescale industrial service applications require infrastructure and reliability, which are today seen as uncertainties.

According to the results of our literature review, many authors identified the potential of wearable computing to gain efficiency improvements in industrial applications. This fact is proved by plenty of publications. However, there is still a lack of comprehensive case study results emphasizing the benefit of wearable computing in this area.

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