Ubiquitous Computing Market and Companies in Finland

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Abstract—**This report tries to clarify the concept of ubiquitous computing (UBI) and to examine it in the context of the Finnish economy. Defining UBI resulted in three different viewpoints: smart environments, embedded environments, and the internet of things. The criteria found from the literature and that interviewees were most satisfied with were: the user need not be aware of the computer inside the device; devices are networked; the system allows every object to connect to every other object, and it influences everyday life. The most important industries in Finland, according to interviews, are: UBI technology (such as sensors, GPS, RFID, and NFC), appliances (such as heart rate monitors and mobile phones), UBI services (such as tailored location-based services or sensoring), automation (such as process automation, real estate automation, or home automation), and traffic or logistics. Future research could study other than technical aspects of UBI, such as user experiences of UBI services or networks of UBI companies in Finland.**

Keywords – UBI; ubicomp; ubiquitous computing.

I. INTRODUCTION

There is no single definition of ubiquitous computing (UBI). The concept of UBI is vague and diffuse, so the purpose of this report is to clarify the concept of UBI and to examine it in the context of the Finnish economy. In particular, we examine how many and what kinds of companies in Finland are involved with UBI. Therefore, we have a need to understand the UBI field.

The aim of this research is divided into two parts: The first is to describe based on the existing literature what ubiquitous and ubiquitous computing means. The second goal is to develop a classification for ubiquitous computing companies in Finland based on national software industry survey and digibusiness.fi data in addition with firms that are funded by Tekes, Space Firms list (from Vesa Hirvisalo), and by examining all the firms that the author found and had the letters 'ubi' in their name.

According to Weiser [10], "Ubiquitous computing is the method of enhancing computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user". In general, ubiquitous computing can be seen as a post-desktop model of human-computer interaction. Ubiquitous computing has many potential applications in industry, transport, and logistics, but also, for example, supporting services for older people and people with disabilities in independent living. It will affect the daily lives of all people in homes and public spaces when the technologies begin to reach these areas [6].

Finland traditionally has strong expertise in the software and electronics fields, but the traditional electronics industry is faltering in Finland [7; 5]. The difficulties of Nokia have been much discussed recently, but can be helped greatly by technology that has the properties UBI has been suggested to have. But, the phenomenon is much broader; a large number of the electronics specialists will be left without livelihoods if a substitute industry does not arise. The world is undergoing the most important technological revolution since the appearance of the internet: the everyday physical and digital worlds are blending together.

Information technology is blending into everyday objects, facilities, and services. We no longer use the computers directly, but they work quietly in the background. Sensors monitor the ambient air quality and, when needed, more oxygen enters the room. A smart house takes care of heating, energy efficiency and safety, and so on.

The aim of this study is to describe the UBI field and act as a pre-study for a further study (survey) to identify how the business research of network **(**what kind of partner chains Finnish UBI companies have) can help UBI companies in Finland to face future challenges and opportunities. The research questions are as follows.

1. What is UBI?

In this research, an attempt is made to create a definition and the instrument for it and a set of criteria which can be classified.

2. What are the criteria for UBI companies?

Developing an instrument for UBI companies. In the future, more and more companies will have some UBI elements in their offering; in addition to the ones that are producing, if you like, the ingredients to make a sandwich, you need the tomato, the cucumber, the meat, the lettuce, and the bread. So there are various layers. But then there are also the ones that use ubiquitous devices in order to make the business more successful. So, with this kind of

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instrumentation, we could classify how 'UBI' a company is.

3. How big is the UBI field in Finland?

An estimate of the size of the UBI field in Finland. What are the Finnish UBI companies? About how many UBI companies are there?

II. RELATED WORK

The literature was searched for criteria for UBI. Other studies have defined ubiquitous computing in many different ways. In 1991 Weiser [9] said: "The most profound technologies are those that disappear." Walther and Burgoon [8] identified two key characteristics of ubiquitous computing systems: physical integration and spontaneous interoperation. Ten years later Weiss and Craiger [11] stated: "the idea behind ubiquitous computing is to surround ourselves with computers and software that are carefully tuned to offer us unobtrusive assistance as we navigate through our work and personal lives. Contrast this with the world of computers as we know them now."

Kindberg and Fox [4] and Greenfield [3] wrote books to attempt to describe the form computing will take in the next few years. "It's about a vision of processing power so distributed throughout the environment that computers per se effectively disappear," said Kindberg and Fox [4]). Greenfield [3] describes the interaction paradigm of ubiquitous computing as "information processing dissolving in behavior." At 2009 Almeida [1] said: "The next computing revolution's objective is to embed every street, building, room and object with computational power".

III. EMPIRICAL RESEARCH

The data for this research were collected in interviews in August-December 2010. Since the purpose was to study the field/definition/market of UBI, an open-ended approach was chosen. Open questions tend to produce a lot of non-responses in mail surveys and thus interviews were chosen as the data collection method. Before the actual interviews, the work of this study was done in three working group meetings in which the author of this paper took an active part. The purpose of the working groups was to identify who should be interviewed, define UBI, and identify what the field is like in general.

The interviews took about half an hour to an hour. These data were analysed by coding the responses on NVivo(NVivo is a qualitative analysis software tool that allows the data for specific topics to be organised, indexed, coded, and queried). All the text was coded to identify different themes and then these codes were grouped into a hierarchy. The process involved sifting through the data, filtering out the significant information, identifying patterns, and constructing a framework for communicating the essence of what is revealed. That whole process was assisted by means of the use of NVivo 8. NVivo facilitates the storage, coding, retrieval, comparison, and linking of data and allowed subject areas (that are typically unquantifiable in text documents) to be counted, compared, and queried.

The interviews were with representatives from three Finnish universities and three foreign universities. All the representatives are experts in the field of UBI, and work as professors, researchers, or senior lecturers. The total number of research years of the interviewees was 107 years! When they were asked how confident they were about their expertise in UBI on a Likert scale (1-5), they gave a mean (4.375) of very confident.

We sought to target informants from various disciplinary backgrounds who were involved in the UBI industry. Foreign researchers were picked from UBI conferences (12th ACM International Conference on Ubiquitous Computing, the Global Internet of Things, Internet of Things, and Workshops of the 1st International UBI Summer School) and researchers from Finland by recommendations and from conferences (Web Squared – Embedding the Real with the Digital). The most important criteria for the interviewees were that their focus in UBI would differ as much from that of the researchers and each other as possible.

To communicate the sampling criteria, a description was prepared that included a description of the types of informants to be targeted. The document was circulated to fellow researchers and Culminatum employees for comments, and some changes were made to its content. The sampling strategy can be considered as a snowballing approach: existing study subjects recruit future subjects from among their acquaintances. Because the researcher is from Aalto University, there are far more Aalto University researchers represented in the sample than there are from other universities.

As a result nine interviews were conducted at six universities. The interviewees included professors, a docent, an associate professor, assistant professors, research group leaders, and a senior research fellow (a description can be obtained from the author). The universities represented in this research are Aalto University School of Science and Technology, Aalto University School of Art and Design, the University of Jyväskylä, University of Oulu, and in comparison University of Madeira/Portugal, Umeå University/Sweden, and Queensland University of Technology/Australia. The data were collected during October-November 2010 by structured face-to-face or telephone interviews and they were audio recorded. The interview questions can be obtained from the author.

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IV. RESULTS

A. Definition of UBI

In autumn 2010, before the actual interviews, we tried to define in a small working group what UBI is. Three working groups met at the Cuminatum office, and involved the researcher and three Culminatum employees. The meetings of the working groups typically lasted an afternoon. We ended up with three different viewpoints:

1. service/human-centric: SMART ENVIRONMENT

Computers used in an environment (home/nature) which enrich the experience in a way that is natural in this context.

2. manufacturing/technology-centric: EMBEDDED ENVIRONMENTS

'UBI is Tron' (operating system). UBI is: a physical device has an embedded computer that has some software that brings some kind of added value.

3. technology-political, network: INTERNET OF THINGS

A device that is connected to other electronics (like a mobile phone that could be a user interface for a coffee maker, freezer, etc.).

According to the interviewees the definition is something like: 'smart environment'/'local UBI environment'/'UBI as services', 'UBI as technology'/'embedded information technology' , 'internet of things'/'new kind of interaction'/'networks of UBI' , and 'third place'. Compared to my own definition, the Smart Environment got five mentions, Embedded Environments got three mentions, and the Internet of Things got two mentions. The interviewees liked my definition (some even very, very much), so all together it seems to be an appropriate definition for UBI.

Marcus Foth (one of the interviewees) used the term 'third place' as compared to UBI when a physical device or a device is connected to other electronics: "the third area is kind of to say, well, the technology is now pervasive, so it's not just limited to being in an office or being at home. You know, you have set up your computer here, with Wi-Fi, so you're just anywhere, in a cafe. So the technology can be everywhere. And I think ubiquitous computing is really about how the different opportunities that we find in these new places can be matched up with design interventions and design solutions. And so, it's really that intersection between what people are doing outside home and outside work. It's like this third, this third space, if you like."

B. Criteria for UBI companies

The goal of the criteria is to define what UBI companies are. The most acceptable criteria, according to the interviews, are: 'augmenting', 'control of breakdowns', 'computational-enabled behaviours', 'ease of design', 'usability' (2), 'controllable', 'obvious', 'present', 'invisible', serves humans' (3), 'accessibility', 'something cool', 'adaptability', and 'effortless'. In comparison to the criteria found from the literature, the most acceptable according to the interviews can be seen in Table 1 below. The biggest consensus was that the user need not be aware of the computer inside the device. Vassilis Kostakos (one of the interviewees) said that the most important criterion, when measuring what UBI is, is: "to what extent the service is either augmenting the environment, or, kind of, hiding the technology and complexity from the users, but still enabling them to do something cool".

TABLE 1. CRITERIA FROM LITERATURE THAT INTERVIEWEES LIKE

Criteria from the literature	Amount of interviewees that chose this criteria
user needs not to be aware of the computer inside the device	5
devices are networked	4
system allows every object to connect to every object	3
influences everyday life	3
interaction that spontaneously appear/disappear	2
does not interrupt user	2
information to our context	2
ideal interaction; interaction feel natural/spontaneous/human	2
devices are inexpensive	2
system allows every object to sense its surroundings	2
connection between virtual/physical world	2
system enhances the environment	1
computers vanish, embed computers	1
user uses several systems simultaneously	1
does not bother user	1
system allows every object to be located from anywhere in the world (mobile)	1
information to our location	1
information accessible just about anywhere	1
user need not to activate functions	1
system is self-adjusting	1
devices work with batteries	1

C. UBI field in Finland

According to the interviews the number of Finnish UBI companies is between less than 20 and thousands. The median answer was 300 companies. The variation is probably explicable because the interviewees thought of either only 'the core'/narrow meaning of UBI or UBI companies in a wide sense.

In this research the biggest challenge was to find all the Finnish UBI companies, because there is no database or list that could be the starting point. UBI firms were examined one at a time from four sources:

1. From the database of firms that are targets of the annual National Software Survey and that had suitable descriptions ('elektr' as in electronics, 'sulau' as in embedded, and 'ubi');
2. From a list of firms that are funded by Tekes;
3. From a list of "Space firms" from Vesa Hirvisalo;
4. By examining all the firms that the author found and had the letters 'ubi' in their name.

I managed to find 359 firms, so according to the interviews I found a pretty comprehensive sample of Finnish UBI firms.

The most important industries, according to the interviews, can be seen at Table 2 below. The most important industry by far according to the interviews is UBI technology; this means all kinds of technology supporting UBI services. The second most important is appliances and only after these comes UBI services. Maybe as the industry grows older the focus will shift to services.

TABLE 2. THE MOST IMPORTANT INDUSTRIES ACCORDING TO INTERVIEWS

Industry	Mentions
UBI technology: sensors, GPS, RFID, Heating, ventilating, and air conditioning/HVAC, Near field communication/NFC	6
appliances: heart rate monitor, mobile phone	4
UBI services: tailored location based services, sensoring	3
automation: process automation, real estate automation, home automation	3
traffic/logistics	3
health care	2

The biggest single estimate – and explanation for it – came from Mikael Wiberg: "It must be thousands, if you include the whole ecology of infrastructure providers, device developers, and service design companies, because it's important to think about all the actors in the ecology around this. And also, every day, all the people are feeding these systems as well. They are not companies, but still, they make the ecology tick."

When asking about what the most important industries are, the most common answers were: UBI technology, appliances, UBI services, automation, traffic/logistics, and health care. These are all big, existing industries, so no surprises arose. Actually, it seemed that every researcher mentioned the industry he is more or less studying. Other industries mentioned were: ICT, environment/energy, clothing, content for UBI services, security (military technology), agriculture, and education. It was also mentioned that infrastructure is not a priority for Finnish UBI companies. Vesa Hirvisalo thinks: "In my opinion a Finnish strength could be personal appliances, and from the other side of UBI: where to find and gather information; the distributed sensor network, and data collection base techniques. UBI systems need lots of infra; also, personal appliances."

When the interviewees were asked where the market or money in the UBI field is, there were two mentions of the process industry. Other mentions were: user-centric services, real estate automation, ubiquitous computing devices, applications combining a device and a service (such as train tickets), health care, infotainment, and a model to help users sell their data and to legitimise companies using people's data (such as location/Facebook data etc.), or building a platform or a set of rules on top on which UBI services will be popularised.

When considering where the money in the UBI field in Finland is, Ismo Hakala says: "the process industry and property automation are quite local and tailored systems. They have the ability to pay; there are clear benefits gained". Market-wise, Nokia, with its background, could definitely take the whole issue of mobility one step further (compared, for instance, to the iPhone). It has a longer history of thinking about the mobile user. Nokia is an interaction company, but it should be a mobility company and an interaction company, demonstrating to a huge population what mobile life could be about.

V. DISCUSSION

In this research, we read the literature and made interviews in order to gain a better understanding of what UBI is and what it is not. There is no single definition of UBI. The concept of UBI is vague and diffuse, so there will probably not even be a precise definition. We do not know precisely what information technology is or how we could then define UBI. UBI should be understood much more as a system: a joint social or organisational or human collaboration matter, not a device connection. In this research we concentrated on three aspects of UBI: smart environments, embedded environments, and the internet of things. The combination of these characterisations seemed to satisfy the researchers who were interviewed. Actually, according to this research, it seems just to be a new kind of combination of the web, social media, embedded, and mobility.

The shift toward ubiquitous computing leads to multiple technical, social, and organisational challenges. It is hoped that large corporations are hiring social scientists. Nowadays companies are full of engineers and computer scientists, but they actually need ethnographers and other specialists.

Additionally, infrastructure providers, together with companies, mobile operators, and application developers, probably need to start collaborating to achieve good user experiences. In the future it would be interesting to study other than technical aspects of UBI, such as user experiences of UBI services or networks of UBI companies in Finland.

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