Intelligent Buildings and pervasive computing – research perspectives and discussions

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Abstract

Intelligent Buildings have been the subject of research and commercial interest for more than two decades. The different perspectives range from monitoring and controlling energy consumption over interactive rooms supporting work in offices and leisure in the home, to buildings providing information to by-passers in plazas and urban environments. This paper puts forward the hypothesis that the coming decade will witness a dramatic increase in both quality and quantity of intelligent buildings due to the emerging field of pervasive computing: the next generation computing environments where computers are everywhere, for everyone, at all times. Where IT becomes a still more integrated part of our environments with processors, sensors, and actuators connected via high-speed networks and combined with new visualization devices ranging from projections directly in the eye to large panorama displays. This paper provides an overview of the field and discusses some central future research perspectives. Research perspectives in the related area, roomware, are discussed in [8].

1 Introduction

The breakthrough of the Internet has triggered a significant increase in intelligent building activities in recent years. Due to development in pervasive computing we are on the brink of an even greater increase: IT components and systems for intelligent buildings will change from being proprietary, specialised solutions with a narrow market to be part of the developing mainstream mass market for pervasive computing where lots of resources will be allocated in the years to come.

In this paper we use the term ”intelligent buildings” about buildings and environments with integrated computing capabilities, since this is becoming an established term when designing buildings. This phenomenon has, however, many names. Mark Weiser [24] from Xerox PARC, US, was the first who coined a term for this kind of computer-augmented environments, when he in 90’ies denoted it as ”Ubiquitous Computing”. Since then a number of related terms have appeared, e.g. Pervasive Computing, Ambient computing, Cooperative Buildings/Roomware (buildings supporting collaboration), Spatial Computing, Augmented Reality (mixing the digital and physical worlds [11]), and Mobile Computing. In an IT research context the more general and preferred term is pervasive computing, and this paper tries to illustrate some common aspects of intelligent buildings and pervasive computing.

In cooperation with the University of Aarhus, the Alexandra Institute ltd. and a number of industrial companies, the Danish National Centre for IT research has created the Center for Pervasive Computing (CfPC) (http://www.pervasive.dk) in the IT-village Katrinebjerg with a budget of 100 mio. DKK for the first five years.

CfPC has made augmentation of people, objects and environments with IT power one of its focus areas, and this includes research in interactive workspaces and intelligent buildings (http://www.daimi.au.dk/ispace). These research activities will be followed by the development of a new interdisciplinary education in what we currently denote eDesign.

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This paper will give an introduction to the domain of intelligent buildings and interactive workspaces, with focus on the achievements so far in the Laboratory of Interactive Workspaces.

2 Background

Intelligent buildings have been in focus in many different contexts during the last decade. Different perspectives have been applied, for instance experiments in intelligent control of energy consumption. Two Danish examples are DTI's Office Vision [17] and Villa Vision [23]. Several research labs around the world have focused on intelligent support for the work that takes place in buildings, e.g. MIT MediaLab [13], Stanford University [6] in USA, GMD [1] in Germany, and Sony [18][19] in Japan.

Finally, various labs and companies focus on intelligent homes. Besides energy this work has included surveillance, audio/video, dishwashers and other hardware. Recently, all of these have been connected to the Internet and a broad spectrum of IT-support is being added. Among the examples are the Aware Home in Georgia (www.cc.gatech.edu/fce/ahri), the Internet houses in London (CISCO) and Stockholm as well as the 'Future Home' which has been constructed at Fornebu outside Oslo (Telenor) [21]. Moreover, companies like Echelon [9] and X10 [26] are marketing operating systems and equipment for intelligent homes and office buildings etc. Such an operating system called LonWorks is in use in Unibank's new headquarter in Denmark [22]. However, the examples mentioned only represent the beginning of this development.

First the development in both network standards and communication standards between computational units is going through a dramatical development. We expect a few powerful standards similar to TCP/IP, HTTP and XML to be widely agreed on. This will create a rapid developing marked based on the convergence between technologies and sectors. Energy management, surveillance, audio/video, media, IT, etc. will be based on a few central networking technologies, and they will do so across sectors like home, office, business, and manufacturing. Moreover, our infrastructures in terms of cities and roads will be included. An indication of this development can be seen in the audio/video sector where manufacturers change from proprietary technologies to industry standards.

Secondly, the development within pervasive computing influences the development. In the years to come, pervasive computing will make a fundamental change to our every-day life. Information and communication technology is integrated everywhere from tables, chairs, pumps, lightning equipment, household machines, and toys over cars, work and leisure environments to roads and cities [14]. New information appliances and new buildings will be developed. The traditional computer as we know it today will disappear and new integrations between the digital and the physical worlds will arise. The driving force in the development is the fact that CPUs, interfaces and communication technologies become cheaper, smaller and less energy consuming and thus can be integrated in new types of products.

Research and development in the construction sector show an increasing activity in the area of applying IT in the industrialization of the construction process. This is, in particular, seen within projects in an EU context. The results so far are modest and limited compared to other sectors such as flight and ship manufacturing. But the current initiatives show promise of improvements in near future.

Finally, it is anticipated that an important factor in the IT-based industrialization of the building construction process is the integration of environmental sustainability both in the process and the final products. The interplay between pervasive computing, IT-based construction processes and environmental management may create important synergy in augmenting buildings with useful and sustainable technologies.

3 Research perspectives related to intelligent buildings

In the following, we discuss what we consider important research perspectives for the development of intelligent and interactive buildings. Along the way, we give examples of activities within the Center for Pervasive Computing that contribute potentially to development of intelligent buildings.

We see at least the following research perspectives related to the intelligent buildings area: 1) Live models of building infrastructure, 2) IT-infrastructure for buildings, 3) Building features supporting the users' work and/or living, 4) The interaction between buildings and the city or landscape 5) Dynamic architecture and adaptive buildings. The development of these new aspects of buildings will also affect the construction process and environmental conditions, thus research in building construction will be affected by the fact that new buildings are integrated with information technology. In the following, we will give examples of the research issues in these areas.

3.1 Live models of building infrastructure

Self-supporting buildings may include ubiquitous information about the building's construction in terms of CAD-models including pipe and cable diagrams which are kept up-to-date such that personnel repairing and maintaining the building can access the information in context. This requires engineers and architects to establish a live building model as part of the construction process, moreover, repairs, tailoring, and re-modelling of the building needs to be registered in the database. The information can thus be accessed and updated from mobile devices like the one envisioned in Figure 1. Such intelligent building support requires development of engineering and architectural standards for modelling the infrastructure of buildings, which in turn requires the manufacturers of building components to adopt these standards.

Figure 1: An electrician with a mobile device that can visualize the always-updated database over the building infrastructure, e.g. pipes and cables in the floor.

3.2 IT-infrastructure for buildings

In the future, the physical infrastructure of a building, i.e. heating, ventilation, doors and access control, is controlled via a network of computers, sensors and actuators. The same network may be the carrier of control for audio and video as well as carrier of audio/video content and other data traffic, see section 3.4. The network will combine wired and wireless components. Companies like Echelon [9] and X10 [26] are marketing such operating systems, network and equipment for intelligent homes and office buildings, an example of such an operating system is LonWorks marketed by Echelon.

In this domain CfPC collaborates with manufacturers of pumps, heating, etc. Work includes the construction of embedded software, e.g. Java programs, which can be executed on small 8 and 16 bit computers [7]. Grundfos and Danfoss are involved in these activities. In addition, we work with control of diverse plants via small mobile devices such as Palm PC's and cell phones.

3.3 Building features supporting the users' work or living

The research in this area is related to the purpose of the building. If it is a private home the focus is on support for family life in the building, including access to relevant information and entertainment as well as support for using the home as base for work.

If it is an office building the focus is on support for people's collaboration around documents and objects. If it is a building for manufacturing or an airport, the focus may be on different forms of robots and transport technologies that have to be integrated in the building.

Finally, design and development support requires integrated support for working with physical models and prototypes in combination with digital documents. These technologies have recently been coined with the term Roomware [20].

In this area CfPC is collaborating with B&O, Danfoss and Telenor about the development of ”intelligent homes”. The Laboratory for Interactive Workspaces undertakes research in development of furniture and rooms that support users' communication and collaboration around design documents, physical models etc. In a work context, many of these activities are related to the new EU-project WorkSPACE, which started January 1st. The result so far has been the development of a software infrastructure combining

Figure 2: 3D-tables and walls supporting collaboration about documents and objects in a distributed project room

spatial hypermedia and collaborative virtual environment [2][4][15], which can run on various roomware components as shown in Figure 2. Landscape architecture, engineering and Industrial design undertaken by companies like B&O, Danfoss and Lego have been the sources of inspiration for the developments.

3.4 The interaction between buildings and the city or landscape

Depending on the purpose of a building it may play different roles in the landscape or ”townscape”. It might have large projection surfaces with commercials, information and entertainment. It might support communication to mobile devices in the neighbourhood Such communication may be information about activities in the building, how to find your way in the building or information about other services provided by the building or the organisations it hosts. Such services to mobile devices are a special case of location-based services, where users of mobile devices may receive information based on their physical location. The information may be received by people entering the building or passing nearby via cell phones, radio LAN or Bluetooth. Users may have personal profiles on their devices filtering location based information receival.

Digital models of buildings and cities can also be used to make the living and democratic processes in cities more interactive and tangible. An example of this is the Karlskrona2 project [16], which is a digital mirror of Karlskrona aiming at creating a forum for debate among the citizens about the development of the city. The digital mirror of Karlskrona is accessible from web browsers, large projection screens and kiosks in the city. Citizens may discuss changes to the city through concrete proposals in terms of model elements entered into the digital mirror of Karlskrona. Such proposals can then be discussed via a kind of 3D chat environment. In this way, citizens in the real city may also become ”citizens” in a proposed virtual city, where an ongoing debate about the real city takes place, see also [25].

Figure 3: Projections in the city as part of the Karlskrona2 project [16].

Some types of buildings, e.g. supermarkets, manufacturing plants, play special roles in relation to transportation and logistics in the environment. Drivers who need to deliver goods need to be able to get information about access conditions, preferred delivery entrance, other trucks in line etc. Building information systems and transport information systems need to be integrated, and the domain of intelligent transport has become a big focus area e.g. in the US [5].

3.5 Dynamic architecture and adaptive buildings

Dynamic architecture is known from experiments made e.g. by the Archigram group [3] in the 1960’ies. Here the purpose was to re-think how we live and work based on high-tech buildings. In relation to intelligent buildings, focus has been on manufacturing, monitoring and use of intelligent materials. The development of intelligent buildings and pervasive computing will of course play and important role in the development of dynamic architecture concepts. Figure 4 shows an example from a project at the Aarhus School of Architecture, about an intelligent building that adapts to a particular landscape’s climate conditions [10].

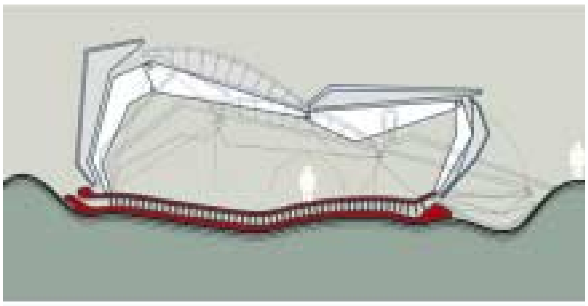

Figure 4: Project about an adaptive building in Rubjerg Knude, Denmark, developed by Architect Tobias Løssing, AAA.

4 Construction process and environmental issues

Finally, the construction process per se, is a research perspective in its own right. There will be a focus on industrializing the building construction process similar to what has happened to ship and aircraft manufacturing. In the building construction process, focus needs to be on development of standards and application of 3D models in the management of the process. There is a huge activity in this domain in the EU, represented by the projects: Distributed Virtual Workspace for Enhancing Communication within the Construction Industry (IST-1999-13365), Electronic Communication in the Building and Construction Industry: Preparing for the New Internet (IST-1999-10303), Intelligent Services and Tools for Concurrent Engineering (IST-1999-11508), Open System for Inter-enterprise Information Management in Dynamic Virtual Environments (IST-1999-10491), Satellite-Based Remote Multi-Project Reporting and Controlling in the Construction Industry (IST-1999-20488).

In this domain the researchers from CfPC have experience from a former EU project entitled EuroCODE (1990-95), where an open hypermedia system and other collaboration technologies were developed and evaluated in the context of the construction of the Great Belt Link. This work has later been elaborated in collaboration with Det Norske Veritas and Norwegian Computing Centre, Oslo, in a project on quality and maintenance information for 3D vessel models.

When considering new methods for constructing buildings and intelligent buildings it is of special importance to take into account the integration of pervasive computing technology, since it is very important to develop the electronic infrastructure in an interplay with the rest of the construction process if one wish to achieve an integrated solution at a reasonable price.

An efficient handling of a wide spectrum of environmental issues is expected to be mandatory for the future development in most sectors of society in the years to come, and this is definitely also the case for the construction of buildings. The interplay between industrialisation of construction, pervasive computing and environmental research will provide new possibilities ranging from reduced environmental stress from construction to environment safe materials to better internal climate in buildings. This requires static solutions as well as ongoing intelligent regulation based on changing use of buildings. This may be illustrated by two examples: 1) In the domain of intelligent energy, the focus is on the optimisation of utilization of energy-based on the entire chain from producer to user. This provides the possibilities of tailoring the use to periods where energy is cheaper, and coordinated use of energy for a coherent area (building, city area, county, or state). Through monitoring of resource usage, weather conditions etc. it is expected to be possible to adapt the usage of energy to cheap periods. In buildings with pervasive computing support, the required infrastructure will largely be in place, and thus it will be possible to achieve a considerable save of effort in the implementation of intelligent energy support for buildings. 2) In many cases, it often appears that the indoor climate in buildings is unexpectedly negative. Through the development of better models for assessment of the effect of peoples use over time, it may be expected that environmental improvements can be devised both in terms of better design and in terms of dynamic management of relevant parameters.

5 Conclusion

The development of intelligent buildings and related areas – primarily environment and industrialisation of the building construction process - will accelerate when combined with research and education activities in the domain of pervasive computing.

With respect to education the main effort needs to be targeted towards engineers and architects. These professions need to develop basic knowledge about the role of IT in relation to buildings and construction processes.

With respect to research, universities and companies have started focusing on pervasive computing. Center for Pervasive Computing at Katrinebjerg in Aarhus, Denmark, has initiated the largest activity in Denmark on pervasive computing, including technologies for the development of intelligent buildings. In the centre, computer scientists, architects, engineers, multimedia researchers, aesthetic researchers and students work together on common projects. The lab facilities including competencies are gathered: 3D-visualisation and simulation, embedded object oriented systems (Java), interactive workspaces, architecture and industrial design, mobile and wireless systems, HCI, robotics, hypermedia and internet-technology as well as research on New Ways of Working. Intelligent buildings will be among the focus areas for research in the Danish Center for Pervasive Computing.

6 Acknowledgements

We wish to thank our colleagues from the Laboratory for Interactive Rooms as well as colleagues from the projects contributing to the work. The work has been supported by the EU ESPRIT LTR Project 31870 'DESARTE', the Danish Research Council's Centre for Multimedia (project no 9600869), the Danish Centre for Pervasive Computing, the Danish Centre for Integrated Design, and the EU IST-2000-25290 project 'WorkSPACE'.

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