GIS-CONNECTED INTELLIGENT BUILDINGS COMMUNITY (INTEBCO)

V. Agnolotti [a], C. Giger [a]

[a] Swiss Federal Institute of Technology (ETH), Institute of Geodesy and Photogrammetry, ETH Hönggerberg, 8093 Zürich CH - (agnolotti, giger)@geod.baug.ethz.ch

KEYWORDS: Spatial Information Sciences, GIS, Architecture, Facilities, Urban, Integration, Building, CAD

ABSTRACT:

Research and development carried out on the "Intelligent Building" (IB) have always been addressed to obtain a building capable to adapt itself to external environmental changes and keep the maximum internal comfort. A well performing IB can require up to 30% less energy than a traditional building for its management. The IB is able to learn how to adapt itself according to specific inputs and to store its "experience" in order to use it in subsequent events. Target of our present research is to connect a group of IBs in order to exploit the experience of each of them to maximize the performances of connected buildings. The connected buildings create an Intelligent Buildings Community (INTEBCO), providing internal co-operation with the aim of optimising comfort, low energy consumption and costs containment for each building. The Community is a living "organism" that, through a net of sensors as "skin", becomes capable to interact with the external environment. On-line and off-line simulations will provide behavioural instructions for each connected building: a central control unit will forward the instructions to the Community. The application scenario is a bank real estate; the test comfort requirement is internal illumination and visual comfort. Our purpose is to enable each building of the Community to communicate data, experiences and instructions to other buildings and building components (adaptive façade and window elements, solar shadings, internal coatings) according to weather changes, maximizing internal luminous comfort performances for the whole community and minimizing artificial lighting usage and costs for each building. A connection between buildings, sensors, simulation, actuators and building components has to be realized through a central control unit that collects input data deriving from external sensors and outputs consequent actions. Tools for the realization of connections are GIS, CAD and simulation programs. The GIS plays the fundamental role of the Information System and tool for integration in the whole system. CAD and simulation programs provide data sources and act as data acquisition tools for GIS.

1. INTRODUCTION

1.1 Motivation

Every building is integrated in an external environment, and this environment is continuously changing. Weather changes can affect the general building behaviour, with heavy repercussions on the internal comfort performance of the building and on the amount of energy and costs needed to keep comfort constant according to assigned parameters.
It has been globally agreed that energy consumption has a significant impact on the environment. Year by year, the built environment has been growing and the demand of high-technology buildings is bigger and bigger, with serious impact on the environment. Energy consumption is not the only building item that impacts on the environment. Other items like the selection of materials and the design for flexibility, site and waste planning, as well as energy planning represent a critical factor in the environmental crisis (Ngowi, 2001). Building and construction highly contribute to the environment crisis by the exhaustion of resource, energy consumption, air pollution and creation of waste (Spence & Mulligan, 1995). According to Dimson (Dimson, 1996) globally, buildings consume 16% of the water, 40% of the energy used annually, and close to 70% of the sulphur oxides (produced by fossil fuel combustion) are generated through the creation of the electricity used to power houses and offices. Furthermore, energy and material input into the construction process increase the amount of total energy needed for building production (Kua, 2002).
The high technology concept of Intelligent Building (IB) was introduced in the United States in the early 1980s. IBs use electronics extensively and are high technology related. Energy efficiency, life safety systems, telecommunication systems and workplace automation are well integrated in the building (Hartkopf, 1997). Building elements and components, Intelligent Façade and internal coatings concur to provide internal comfort. Since the Nineties, a lot of research and development has been done on the IB, in order to obtain a building capable to adapt itself to external changes, keep the maximum internal comfort and optimize the energy usage.

Energy usage in the building is related to the following local factors:

- climate (sun elevation angle, sun radiation, temperature, wind force and direction, rainfalls);
- exposure and surface of the ground (slope angle, form, geometry, proportions);
- location, geometry, dimension and volume of the surrounding buildings, topography, areas with water and vegetation (reflection, emission, changing in the thermal body). (Gallo, 1998) (Fig. 1)

Studies and research have proved that a well performing IB can require up to 30% less energy than a traditional building to keep the internal comfort in the quality level required by the energy consumption laws and regulations. Intelligent Buildings have been successfully designed and realized and their performances have been increasing in the last ten years. In the past few years design and engineering of IBs have provided not only major advances in office technology, but also better physical and environmental settings for the occupants (spatial, thermal, air, acoustics and visual quality, plus building integrity versus rapid degradation). Research on IBs is now addressed to promotion of ecological sustainability (energy), economic sustainability (costs) and social/cultural sustainability (cultural heritage) (Kua, 2002). The new challenge is to dramatically improve building performance while dramatically decreasing energy requirements and improving environmental performance (Hartkopf, 1999).

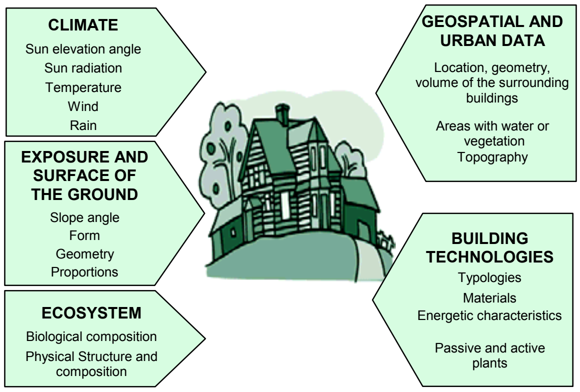
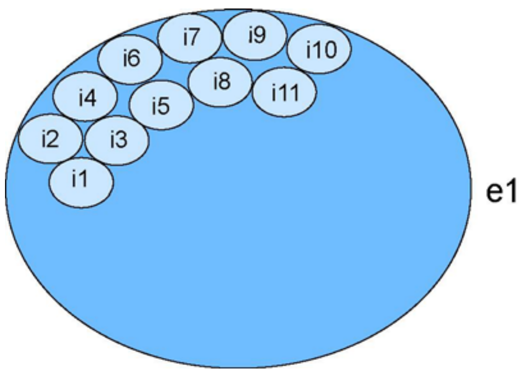


Figure 1. Factors related to the building planning process

1.2 Aims

The Intelligent Building is able to learn how to adapt itself according to specific inputs, e.g. detecting external environmental changes and reacting properly to keep constant the internal comfort. Through the learning process, the IB gains experience that can be stored and eventually used in subsequent events.
Target of our research is to develop a system providing communication within a group of IBs in order to exploit the experience of each of them to maximize the performances of the connected buildings. In other words, to create an Intelligent Buildings Community (InteBCo) that provides internal cooperation with the aim of improving the performances of each building and of each room in every building in terms of comfort, low energy consumption and costs containment, also according to users' interactions. The Community represents a big "social organism" capable to interact with the external environment and the users.
All the connected buildings are supposed to behave like cells in an organism. (Fig. 2)



e1: organism
i1…in: cells or Intelligent Buildings

Figure 2. Each Intelligent Building is a cell in the building organism

Core and innovation of our research is the idea of handling a group of buildings as a leaving being. Learning from nature, we will build a system that will imitate a biological behaviour by mean of some of the peculiar GIS functionalities that we will integrate and use in our final application.
No existing commercial GIS will be used, but some components will be combined in a new information system that will imitate a living organism.
A group of similar buildings (cells with similar behavior) will be assumed to behave like an organism: each cell goes through a process of learning and exchanges local experience with the other buildings.
Communication in the Community will be provided by the GIS-based application we will develop, that will be capable to handle reciprocal topological relationships, connections and interactions between buildings, sensors and environment. According to on-line or off-line simulations, each IB would get instructions from a central control unit about how to behave in order to maintain high quality internal comfort and would forward recommendations to the Community. In other words, each building will make experiences and communicate them to the other buildings proposing possible adaptations via some of the GIS functionalities. The other buildings will get the results of another building's experience and will be able to follow the recommendations, according to local constraints. Human decision plays here an important role: recommendations will be sent and made available and understandable through our GIS-based application, but human beings will take the final decisions.

Our system plays the role of information system and tool for decision support, acting as a central control: it collects the experiences, finds out which other buildings are involved and forwards recommendations. Locally each building will decide whether acknowledging the information or not.
According to local constraints, humans will take decisions about the adaptations of the other buildings. Buildings can acknowledge the recommendations only if they have the characteristics of adaptability: this means that the present research can be applied to IBs, but not to simple buildings. Furthermore, connected buildings will be of the same usage, in order to reproduce the organism situation, with similar cells.

2. IMPROVEMENT OF THE INTELLIGENT BUILDING TOTAL PERFORMANCE UTILIZING A GIS

2.1 Basic hypotheses for the research

The research is focused on the two main topics of total performance and communication within buildings, according to the following hypotheses:

- Performances of a group of buildings are of higher quality (optimized) than when each building is standing alone.
- A group of buildings can behave like an organism.

The first hypothesis on which the present work is based is the assumption that providing communication within a group of buildings is a new, smart way to enhance global and local building performance exploiting the experience of each building to bring advantage to all the others.
Therefore, a focal point is represented by the selection of the application scenario.

2.2 Application scenario: lighting and visual comfort

The selection of the scenario has been carried out by trying to answer the following questions:

- in which scenario does the community behavior bring more advantages?
- where are connected IBs more powerful?

Different scenarios and building performances have been analyzed and compared, with the aim to understand which of them is more suitable to prove and/or support the research hypotheses. If every Intelligent Building is already capable to optimize the internal performance, why should it be connected to other buildings? Which effects are expected by this operation? Which are the situations in which buildings can take advantage of the community structure?
The following topics have been analyzed:
Global scenarios

- lighting
- heating/energy
- energy consumption
- weather protection
- security

Lighting and visual comfort will be the application scenario for our research.

2.3 Technology

According to the research hypothesis and target, a connection between buildings, sensors, simulation, tools for decision support, actuators and building components has to be realized through a central control unit that collects input data deriving from external sensors and outputs consequent recommendations according to on-line or off-line simulations.
Tools for the realization of connections can be very many: GIS, CAD, Simulation Programs, Building Automation, Facility Management, SAP, Neural Networks, 3D Visualization. (Fig. 3)

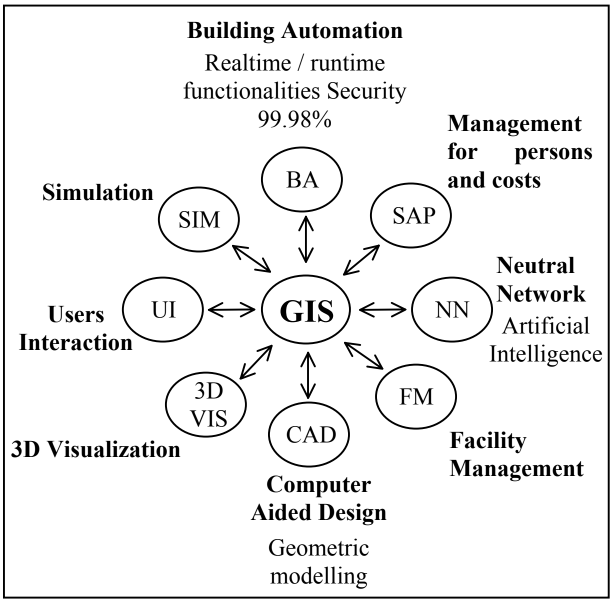


Figure 3. Tools for connection of cells in the building organism

According to the basic assumptions, each IB (or cell in the building organism) makes local experiences and adapts itself to the local environmental changes. Experience and adaptation parameters will be sent to the organism central control, to be interpreted according to the local natural and built environment for each building. According to topological relationships of each IB and the environment, the GIS-based central control will be planned and developed to translate the experience of the first building into suitable recommendations to each of the other buildings. Locally, in every building the user will decide whether accept a default standard solution or to choose interactively in the palette of provided recommendations. (Fig. 4)

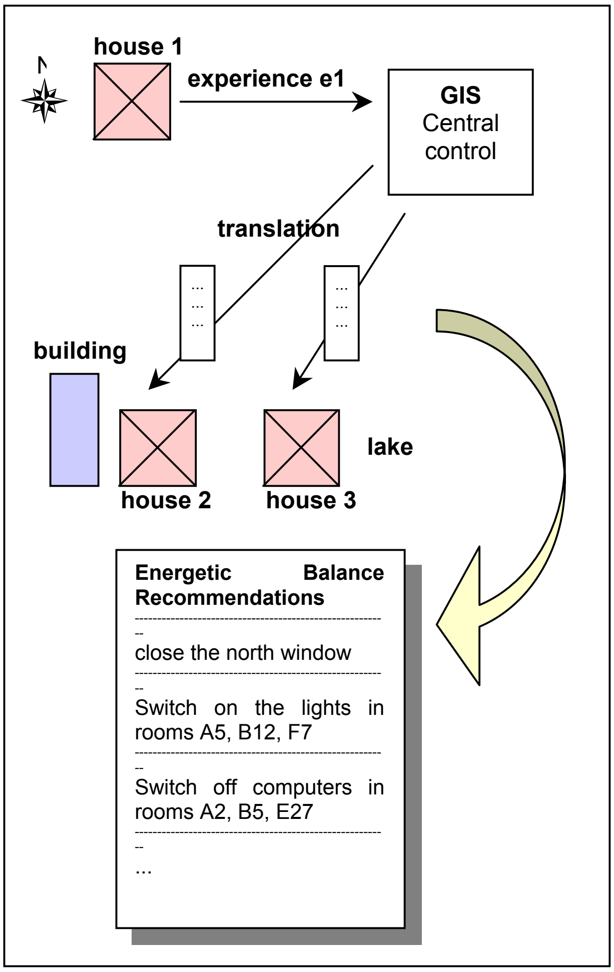


Figure 4. Our GIS-based central control as a "translator" of single experiences into targeted recommendations

The two main GIS capabilities are the key tools for success in communication of experiences and adaptability of buildings:

- topology/geographical handling of data (built and natural environment around each building is taken into account in the translation of recommendations);
- decision support: the system presents a list of recommendations to the user, who can autonomously decide how to behave.

The major GIS functionalities are the only ones that can play the basic, fundamental role of Information System and can support integration.
The GIS functionalities role will be:
- data management;
- control of communication of sensors and between sensors and control information;
- realize what is happening in one building and find out the impact on the other buildings, and therefore:
- perform analysis on data and produce building control data (recommendations) on basis of what other tools provide;

- provide recommendation scenarios for decision support;
- transfer the recommendation data to the control unit in order to forward them to the other buildings.

2.4 Data

The GIS-based database will contain:
- topology (absolute and reciprocal position of the buildings);
- attributes of the buildings (kind of buildings, usage, etc.)
- present or expected attributes of the rooms in each building (rooms utilization; target values for internal comfort: target range of sensor-value, also according to the rooms utilization in the building);
- additional attributes (dependencies/relationships of values and parameters:
    - static (pre-defined scenarios)
    - dynamic (coming from the results of internal or external simulation (on-line or off-line), also according to users' interactions and human perception.

Collecting experiences and data, producing new information out of the existing and provide decision support is the role of a GIS system.
Other tools are not designed for system integration. Some of them, like CAD and Simulation Programs, can provide data sources and therefore can play the role of data acquisition tools for our GIS-based system.
All other tools to be connected to our system must have an open, known structure for input (data/interface) and output data (DB structure or export file).

3. CONCLUSIONS

The present research is focused on increasing the Intelligent Building's total performance by means of GIS technologies and aims at giving an interdisciplinary approach to the problem. Research, literature, design and construction have so far provided high quality IBs capable of answering to the main request of adaptability. This topic has been very well investigated and now research is setting new targets and challenges. It is not enough anymore to realize a very well performing building but too much energy consuming and it is not cost effective to design a new building for each new location without taking into account the experience of other buildings in other contexts.
Attempt of present research is to give a new solution to enhance IB performance and contain energy usage by taking advantage of disciplines that until now have never been connected to building design.
The core functionalities of a Geographic Information System are able to make a building "realize" where it finds itself, how natural and built environment are, which resources are available and which are the reciprocal relationships within all these elements, in order to produce a cooperative organism able to optimise the total behaviour. Each cell in the organism doesn't loose its identity, because the whole system is able to respect local constraints, but can take advantage of the community behaviour to strengthen and power its quality and performance.
Our on going research is also trying to prove that not necessarily a wide amount of very complex technologies have to be used and connected to reach our target: by using the very powerful GIS capabilities as the key of the whole project and by focusing on a definite scenario we will be able to single out the strictly needed technology, in the general attempt to lower complexity and produce a prototype available and easy-to-use.

4. REFERENCES

Asimakopoulos, D. N., et al., Energy and climate in the urban built environment, James & James, London, 2001.

Boed, V., et al, Networking and integration of facilities automation systems, Boca Rato CTC Press, 2000.

Clark, G., Metha, P., Artificial intelligentce and networking in integrated building management systems. - In: Automation in Construction, vol. 6, pp. 481-498, 1997.

Clements-Croome, T., What do we mean by intelligent buildings? - In: Automation in Construction, vol. 6, pp. 395-400, 1997.

Daniels, K, at al., Bauen für die Zukunft, HL Technik AG, München, 2002.

Daniels, K, The Technology of Ecological Building, Basel ,1997.

Dimson, B., Principles and challenges of sustainable design and construction. - In Industry and Environment, vol. 19(2), 1996.

Flourentzou F.; Roulet C.-A., Multicriteria analysis of IEQ in sustainable buildings outline of a methodology EPIC 2002 AIVC Conference Proceeding, Lyon ; October (2002).

Gallo, C.: Architettura ecosistemica, Gangemi, Roma, 1998.

Gassmann, O., Meixner, H., Sensors in Intelligent Buildings, Wiley-VCH Verlag, 2001.

Gay J.-B.; Homem de Freitas J.; Ospelt Ch.; Rittmeyer P.; Sindayigaya O., Standardizing Sustainability : Creating a Sustainability Indicator for Buildings Journal of Urban Technology // Vol 4, Number 2, pp. 53-67 ; (1997).

Gay J.-B.; Rittmeyer P., Impact environnemental des constructions - Comparaison de variante d'implantation CISBAT'97 - Lausanne ; octobre (1997)

Guillemin A., Morel N., Experimental results of a self-adaptive integrated control system in buildings : a pilot study Solar Energy, Elsevier Science Ltd // 75(5), pp. 397-403 ; May (2002)

Guillemin A.; Molteni S., An energy-efficient controller for shading devices self-adapting to the user wishes, in: Building and Environment // 37(11), pp. 1091-1097 ; November (2002).

Guillemin A.; Molteni S.; Morel N., Application of Genetic Algorithms to adapt an energy efficient blinds controller to the user wishes CISBAT 2001 - EPFL // pp.331-336 ; 3 - 4 octobre (2001).

Guillemin A.; Morel N., An innovative lighing controller integrated in a self-adaptive building control system Energy & Buildings, Elsevier Sciences // 33(5), pp. 477-487 ; May (2001).

Guillemin A.; Morel N., Experimental assessment of three automatic building controllers over a 9-month period CISBAT 2003 Proceedings, EPFL, Lausanne // pp.303-308 ; October (2003).

Hartkopf, V. et al., An integrated approach to design and engineering of intelligent buildings – The Intelligent Workplace at Carnegie Mellon University. - In: Automation in Construction, vol. 6, pp. 401-415, 1997.

Hartkopf, V., Loftness, V., Global relevance of total building performance. – In: Automation in Construction, vol. 8, pp. 377-393, 1999.

Hendriks, L., Van der Linden, K., Building envelops are part of a whole : reconsidering traditional approaches. - In: Building and Environment, vol. 38, pp. 308-318, 2003.

Kua, H. W. et al., Demonstration intelligent building – a methodology for the promotion of total sustainability in the built environment. – In: Building and Environment, vol. 37, pp. 231-240, 2002.

Mertens, E., Das bioklima städtischen Baustrukturen : eine Analyse- und Bewertungsmethode für den gesundheitsorientierten Städtebau, Köhler, Berlin, 1997.

Molteni S., Morel N. (EPFL); Priolo C. (Conphoebus,I); Bakker L. (TNO, NL); Heimonen I. (VTT, FIN), Smart Window : A Window Component with an Integrated Control of Blinds and Ventilation CISBAT 2001 - EPFL // pp.297-302 ; 3 - 4 octobre (2001).

Ngowi, A. B., Creating competitive advantage by using environment-friendly building processes. - In: Building and Environment, vol. 36, pp. 291-298, 2001.

Oestreicher Y., Bauer M., Scartezzini J.-L., Accounting free gains in a non residential building by means of an optimal stochastic controller Energy and Buildings // Vol. 24(3) ; (1996).

Roulet C.-A., Indoor environment quality in buildings and its impact on outdoor environment Energy & Buildings, Elsevier // 33, pp. 183-191 ; January (2001).

Roulet C.-A., prEN-ISO 13790 - A simplified Method to Assess the Annual Heating Energy Use in Buildings ASHRAE Transactions : Symposia, ASHRAE, Tulie Circle NE , Atlanta (USA) // 108, Part 2, pp. 911-918 ; November (2002).

Roulet C.-A., Solar Energy and Global Heat Balance of a City Solar Energy, Elsevier // 70/3, pp. 255-261 ; Mars (2001).

Roulet C.A.; Cretton P., The influence of the User on the Results of Multizone Air Flow Simulations with COMIS Energy and Buildings // 30, pp. 73-86 ; (1999).

Scartezzini J.-L., Gay J.-B., Molteni S., Roulet C.-A., Morel N.(EPFL-LESO-PB); Jaccard P.-A., Porchet L. (EPLF-LEM); Schlaepfer R., Jolliet O.(EPFL-GECOS); Ortelli L., Svimbersky M. (EPFL-TTPA), Negentropy House : a Sustainable Building Designed Through an Interdisciplinary Approach CISBAT 2001 - EPFL // pp.113-118 ; 3 - 4 octobre (2001).

Scartezzini J.-L.; Montavon M. (EPFL); Compagnon R. (HES-SO), Computer Evaluation of the Solar Energy Potential in an Urban Environment Proceeding of EuroSun 2002 Congress, Paper No 191, CD-ROM ; June (2002).

Smith, S., The integration of communication networks in the intelligent building. – In: Automation in Construction, vol. 6, pp. 511-527, 1997.

Wigginton, M., Harris, J., Intelligent skins, Oxford AP, 2002.