Knowledge-Based Services in Building Management: Online Advisory Expert System

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ABSTRACT: The results of investigations within the scope of the "Knowledge Based Services in Building Management" research project (Wissensintensive Dienstleistungen im Gebäudemanagement -WiDiG) and the concept of an online advisory expert system (consulting module) for building automation are substantiated in this paper. The trends of the further development of control algorithms of such systems are described. The objective of this project is to investigate the possibility and to produce recommendations for unification of the existing building automation systems and building management systems within the framework of a unified concept.

1 INTRODUCTION

Appearance of new services in facility management is possible only due to efficient usage of informational potential present in modern buildings. Such services (knowledge-based services) use information that is already present among the general data. Efficient usage of this information requires a close connection between the building automation and building management. This connection is carried out due to the application of universal database structures and open data profiles. Within the boarders of this project such structure has been developed and certain proposals to the open data profiles have been made. The concept of the online advisory expert system is presented here as an example of the knowledge based services in building management. In order to test the connection between the building automation and building management, a part of such unified database was created that was used further for conducting of experiments within this project.

2 STATE OF THE ART

Sufficient part of investments in the projects of construction or reconstruction of the buildings falls to the share of the building automation and building management. Joint action of such systems (i.e. common use of information and resources) has been difficult for a long time for the reason of extremely high costs of their combination. At present, as a result of attempts of standardization of information exchange methods (e.g. Data Communication Protocol (DIN EN ISO 16484-5, BACnet), Home and Building Electronic System (EN 50090, Konnex), Control Network Protocol (EN 14908, LONWORKS)), on the one hand, and reduction of hardware and software costs, on the other hand, combined action of these systems became profitable. The future trends in building automation are also described by Dietrich (2003a, b).

At present, the research in this line is conducted in many universities and research institutes. In (Laukner 2000), a decentralized intelligent control of building comfort parameters was proposed. The ventilation operation is optimized according to the criterion of minimum energy consumption with simultaneous support of air temperature within given limits. The proposed method guarantees the air exchange in buildings required by hygienic and construction regulations. In (Kuntze & Nirschl 1998), the development of an intelligent heating controller was proposed in order to optimize the admissible values of temperature depending on the initial climate and the number of persons in the building. In (Tamarit & Russ 2002), the Smart Kitchen project was presented. Its aim is to design a decentralized intelligent control system for a kitchen. Using a large number of sensors, this system has to recognize the situation and to react adequately using various actuators.

Recently, the capabilities of teleoperation and remote access have been used more frequently in building automation (Tarrini et al. 2002, Sauter & Schwaiger 2002). In (Corcoran et al. 1998), device variation for access to different home systems of automation and visualization of control processes such as web browsers, telephones with incorporated

Java engines, TV sets with remote controls, and pocket computers with Internet access are described.

Modern state of building automation algorithms does not allow to involve users into the process of resource and energy management in a real time mode. At present, we do not yet have algorithms that could be able to explain to the user various alternatives of his actions to reach the desired comfort level, their sequence and their results. The subjective ideas of a user about what comfort is should be the source information for such algorithms. Information on energy consumption should be demonstrated to the user as an output, which may help him to find his individual compromise.

The present state of the art in the building automation, as it was already shown above, makes it possible to provide new services to users of buildings. Thus new solutions appear that make it possible to use limited resources more efficiently (Dementjev & Kabitzsch 2004b).

3 CONCEPT OF ONLINE ADVISORY EXPERT SYSTEM (OAES)

Considering different phases of building use, we can conclude that certain rooms in it should be considered main objects of automation. Note that, first of all, the main needs of users such as comfort, ergonomics, and efficiency should be taken into account. Consider the following examples of interaction of different automation subsystems aimed at meeting these requirements:

- Window opening with actuator connected to the room automation with using the blocking of energy supply in incorrect controlling cases, i.e. „heating actuator off";
- Use of building heat accumulation ability;
- Reduction of the lighting costs through various regulating strategies depending on the outdoor light intensity and room occupancy.

From the technical point of view, each building is a dynamic system offering therefore a certain potential for optimization. The analysis of the influence of various measures (e.g. choice of the required value of room air temperature, of air conditioning and of the way of heating) on the energy consumption proved that relatively large energy potential – up to 70 % - can be saved via reduced air conditioning (Hoh 2002).

At the same time, a building is a complex composed of a number of various service systems. The most processes within a building proceed in single rooms. As soon as the processes in each room are optimized, the whole building reaches the state of optimal mode.

Based on the most important cause-and-effect relations of physical processes in building automation (Dementjev & Kabitzsch 2004b), we can define several important rules for arranging such functional relations:

- „Heating actuators" can be replaced by „sunblinds", „windows", „ventilation", „lighting" and „inner heat sources". In former three cases the free of charge transportation of the necessary heat energy from outside into inside is used;
- „Cooling actuators" can be replaced by „sunblinds", „windows" and „ventilation", so the free of charge transportation of the needless heat energy from inside into outside;
- „Ventilation" can be replaced by „windows" , thus the free of charge transportation of the fresh air from outside into inside;
- „Lighting" can be replaced by „sunblinds".

The OAES was mainly aimed at solving the problem of optimal control of various subsystems of building automation. As a criterion of control optimality, the cost of the consumed heat and electric energy under supporting a given comfort level was taken.

The OAES should provide a user with the required information about the current state of the building (about the comfort level and the corresponding cost of its support), as well as recommendations in order to optimize the control of subsystems (suggestions of changing the setting of the building for controllers of temperature, illumination and recommendations for closing a window, opening jalousies, etc). The basic tasks of the OAES are as follows:

- consulting (short- and long-range data collections, recognition of the situations that lead to nonoptimal energy consumption, real-time calculation of the cost of the energy consumed, prediction of the development of different situations, consulting in itself),
- the connection with the building management (relation with external databases, remote access for users (visualization)),
- the connection with the lower automation level (the arrangement of connection with field level of automation, logical connection with a building (determination of the current building state)).

The Advisory System is based on two different working regimes: the advisory one and the one of automatic optimization. In case of the advisory mode, the actual situation in the room, including the actual costs for using and advised recommendations for energy saving, is presented to the user. In case of the automatic optimization mode, the recommendations will be changed automatically by variation of the desired values. The automatic optimization can be shut down if needed. Figure 1 illustrates algorithms of the energy consumption optimization.

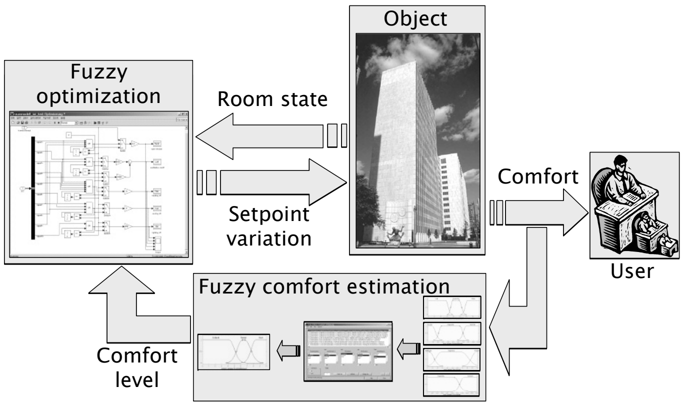

Figure 1. Algorithms of the energy consumption optimization.

Details of the online advisory expert system's architecture and of its realization are adduced in (Dementjev & Kabitzsch 2004a, b).

The main difference between the existing solutions and the Online Advisory Expert System consists in improved communication with the user based on a universal and open platform (open and independent service arrangement using the guidelines of Open Services Gateway initiative (see also www.osgi.org)). This system is not a purely automatic control system. It performs also consulting functions, e.g. the recognition of situations in the case of false or nonoptimal control of heating, ventilation, sunblinds etc., and warns the users (giving recommendations for optimal set point adjustment of controllers).

4 SIMULATION RESULTS

For checking the efficiency of the developed algorithms, a model showing the basic physical processes in a room was used. Results of the first simulations made in MATLAB proved that the offered algorithms let save up to 32% of consumed energy by heating (simulation of two weeks in winter with and without consulting module) and up to 36% of consumed energy by cooling (similar simulation for summer). Simulation results are presented in the Table 1.

Table 1. MATLAB simulation results for energy consumption.

Subsystem	Simulation period	Energy consumption, kWh		Saved energy, %
		conventional	with OAES	
Heating	2	39.82	27.32	32
Cooling	week in	0	0	0
Lighting	winter	6.08	6.07	~0
Heating	2	2.75	1.39	50
Cooling	week in	4.25	2.76	36
Lighting	summer	1.14	1.14	0

For solving the task of the prognosis of changes in the level of comfort and energy consumption, a neural network model showing the basic physical processes in a room was developed. The data of the simulation of the room model in MATLAB Simulink was used for training of the neural network. Neural network imitates the system of 14 inputs (actuators state, outer environment parameters etc.) and 1 output (e.g. comfort parameters: room temperature, light, air humidity or CO_2, or energy consumption for heating, lighting or cooling). Figure 2 illustrates neural network structure.

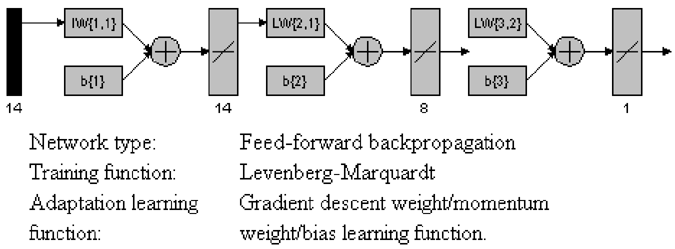

Figure 2. Neural network structure in MATLAB.

Figure 3 presents the neural network simulation results for room temperature. The maximum relative error by simulation is 3,53 % and the average relative error is 0,96 %.

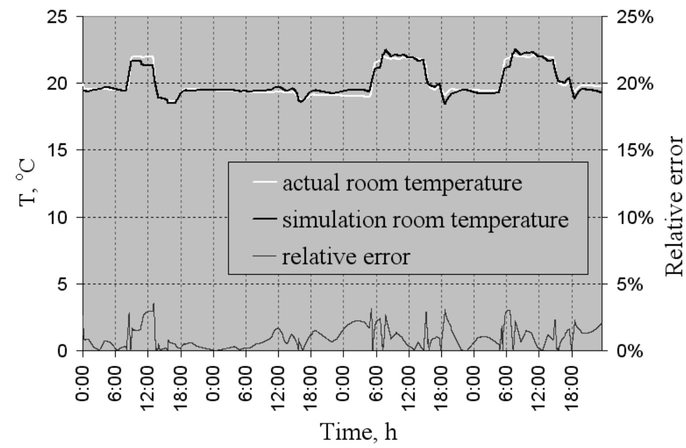

Figure 3. Neural network simulation results for room temperature.

To test the possibility of a hardware implementation of consulting algorithms, a physical model of a room (Fig. 4) was developed and produced. This model was equipped with all required sensors in order to determine the comfort level (sensors of indoor and outdoor temperature, relative humidity, and lighting), actuators (sunblinds, fans, lamps, heating and cooling elements), and controllers (a regulator of temperature and ventilation and a controller of the sunblinds and lighting).

Figure 4. Room model for testing of the algorithms.

5 CONCEPT OF A DATABASE-STRUCTURE

As it was already mentioned in the introductory part, within the present project a universal database structure was developed providing the base for the cooperation of the building automation and building management, i.e. the base for new services in the building usage. More information, especially about this structure, is given by Schach et al. (2004), or by the conference article “Knowledge-Based Services in Building Management” by Schach & Otto.

To test the efficiency of the offered database structure, a part of it meant for data collection in the building automation and serving as an interface between the building automation and building management was realized. It is presented in the Figure 5.

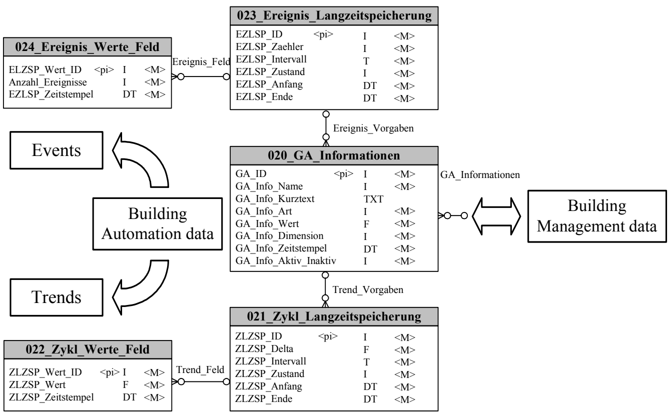

Figure 5. Database realized part’s structure.

That resulted in creation of the program LonMonitor capturing information in building automation (e.g. from LONWORKS) and saving it as events or trends (in the format MS Access). The program provides a wide range of possibilities of data acquisition filters setup, data collection's automatic start and stop, physical interface selection etc. Different variants of remote program's access to the building automation data are studied now. The gateway OSGi to LONWORKS has been already applied as one of the variants (see also Echelon 2003).

Developed program can be used not only as a simple interface between the building automation and building management, but also for the control network monitoring with the purpose of control processes investigation. The main suppliers of information for investigation of the control processes are the so-called network variables (i.e. process variables) whose values are recorded by the LonMonitor in the universal database together with their time stamps. The LonMonitor directly interacts the database of the automation system project (for LONWORKS it's LNS database) in order to get access to the process data chosen by the user in advance by means of the filters system. Gained data saved in the database are used later for the process analysis, its protocolling etc.

6 CONCLUSION

Consulting algorithms were developed on the basis of fuzzy logic and neural networks with corresponding development and simulation environment and the simulation results already exist. In order to test the algorithm, a room model in MATLAB Simulink (representing the most important physical features of a room) and a physical room model were made. During the testing of the proposed service models, an embedded server with OSGi framework was installed and the possibilities of remote access to field bus (LONWORKS) per Internet were proved.

7 ACKNOWLEDGEMENT

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