Building Automation by Intelligent Control of its Environment

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Abstract: The fast development of digital technologies has contributed to building industry in the adoption of sophisticated strategies of automation. These strategies are oriented to control of environmental variables in the different parts of a building provided with high standards of performance in terms of both power saving and human comfort aspects. Control strategies can be expressed by means of rules that could be processed by the inference motor of an expert system. The rules of automation in this system will allow for a better integration of devices and will facilitate their interaction with the elements that define the operation of an intelligent building. According to the distributed paradigm currently used in building automation, the expert system located in the supervision computer will carry out specific functions of cooperation and intelligent coordination, reserving control strategies of each building sector for local controllers. As it is shown in this article, the use of technologies based on artificial intelligence to model and control the behavior of building automation systems contributes to optimize its performance in terms of comfort, security and energy saving.

Keywords:

Expert Systems, Distributed Control, Building Automation

1. State of art

The word “domotics” comes from the French word "domotique" that could be defined as: "the set of services provided by technological systems which are integrated to satisfy the basic needs of man and his closest environment in terms of security, communication, power management and comfort.”[1]. In fact, the word “domotics” does not try to give name to a new technology, but to a set of services which are integrated in the house for a better management of aspects such as comfort, security, power management, communications, information and flexibility. In this sense, domotics can be understood as the discipline that studies intelligent infrastructure development, as well as the technologies of information in buildings.

In the last years, words such as intelligent or domotics have been used in an indiscriminate way. However, in many occasions, they have been employed without a correct understanding of its actual meaning. The computer science sector was the one who began to use the “intelligent” term to distinguish those terminals with capacity of data processing from those without that capacity (non-intelligent).

Generally, the term used is domotics when it is applied to home and intelligent buildings when applied to buildings. At the beginning of ´80s, the specialized magazines began to talk about buildings with particular characteristics in terms of comfort services provided in close relation to their environment such as "intelligent buildings", "ready buildings", "automated buildings", or inclusively "buildings electronically optimized". Nevertheless, a standardized definition does not exist of what is an intelligent building.

A definition agreed in the International Symposium on the matter, carried out in 1985 in Toronto, is: "an intelligent building combines innovations, technological or no, with a competent management with the object of maximizing the return of the investment" [2]. A definition contributed by AIBI (American Intelligent Building Institute) is: "a building that uses the four fundamental elements of construction: structure, systems, services and management, as well as its interaction, optimized with the object of maximizing the return in the investment and providing an atmosphere with efficient, comfortable and highly advisable work". Another definition of EIBG (European Intelligent Building Group) consists of: "a building that allows users to develop to their highest standards of efficiency at the smallest cost of operation and that uses its resources efficiently”. This means that the building must provide fast answer, highly efficient, and provide for the generation of an atmosphere of support to the user for the attainment of his business objectives" [3]. Another definition contributed by the DEGW (international An building design consultancy company) states the following: "an intelligent building is one that offers suitable answers to the user and has the ability to adapt to the new technologies or changes in the organizational structures".

Intelligent buildings, besides to fit their operation to certain parameters in agreement with established programs, count on advanced communication and computational resources. In order to achieve this, they add to the pure automation of management, security and power saving, an integrated infrastructure that allows to the maximum benefits in the fields of tele-communications and office automation. In synthesis, intelligent buildings emerge from a conjunction of technology and surroundings with views to the attainment of the best possible strategies of environmental comfort.

It can be affirmed that present tendency in intelligent automation consists of the employment of distributed control [4]. In order to achieve this, intelligent building designers proceed to the distribution of independent regulators that communicate with a central computer. Under this scheme, functions assigned to the controllers are those of regulation, monitoring, calculations and saving of energy [5]. For the central computer, designers reserve non-crucial functions such as auditory, visualization, optimization and maintenance.

Expert systems can be defined as a class of computer programs that are able to handle heuristic problems. These problems normally require specialized human intervention for their resolution [6]. They are developed with the aid of field experts, who reveal information about those mental processes that allow them to solve the different problems. The experts contribute knowledge on how solving ill-defined and unstructured problems, which most frequently involve diagnosis or planning.

Expert systems technologies are particularly useful when, by means of suitable techniques of knowledge engineering, they can capture the knowledge of an expert and represent it in a systematized way for its usage in automation and control tasks [7]. Expert systems are then able to reflect, with the proper limitations of an automated mechanism, the expertise in the use of strategies of regulation and control acquired by human experts who have incorporated them to their cognitive structures after multiple situational experiences in the resolution of different automation and control problems.

2. The expert system

A. General Characteristics

The roots of expert systems include many disciplines; in particular, one of the main roots of expert systems is the area of information processing in the human mind, denominated Cognitive Science [8]. The cognition is the study of the way in which humans process information. In other words, cognition is the study of the way by which people think, specially when solve problems.

In this sense, study of the cognition is very important when it is oriented to achieve that computers emulate human experts. In particular, in the developed expert system described in the present work, specific knowledge elicitation techniques such as analysis of protocols were used with the purpose of inferring experts knowledge concerning automation of buildings and modeling this operative knowledge in terms of production rules [9].

Therefore, the developed expert system is based on rules of production oriented to model control strategies. In a system based on rules, the knowledge base contains the domain knowledge necessary to solve problems, codified in form of rules.

B. Structure of the System

The developed expert system contemplates the following systems related to general aspects of global building automation:

1. System of comfort management
2. System of security management
3. System of power saving management

1) System of comfort management

This system is constituted by the system of building light control of and by the system of building temperature control.

The system of light control is made up of two light sensors; one is a sensor of natural light located near the windows in the different rooms, which stands for detecting the level of light coming from outside. The other is a sensor of artificial light placed just under the ceiling, approximately in the center of the different rooms, in order to determine the level of light coming from the lamps located inside each considered space.

The other component of the light control system is a presence sensor that determines if there are people in the room. The system first determines if there is people in the room and if there is, then takes the value from the sensor of natural light and determines whichever lamps of the room is necessary to activate in order to have a certain level of illumination within the room.

For example, if it is at night the sensor of natural light will accuse that there is no originating radiation from the outside and the system will turn on all the lamps. If it is by day, and the level of originating radiation from the solar light falls within the ranks of comfortableness of a person, then the light control system will determine that it is not necessary to turn on any lamp. In any of the aforementioned cases, the element in charge to turn on a lamp is the corresponding actuator which is determined by the program.

In general, except slight variants, in a given space, the system of temperature control is made up of a thermostat, a temperature indicator, a hot water valve, the cold water valve and a damper for outer air flow control.

The system takes the value from the temperature sensor and according to this value it opens or not

the damper of outer air and the cold or hot water valve. For example, if the temperature in the room is 10 degrees Celsius, the hot water valve will be half open, the damper of outer air will be open and the cold water valve will be completely closed.
Another example is that the temperature sensor is indicating that the temperature is 35 degrees Celsius; in this case, the damper of outer air is opened, the hot water valve is completely closed and the cold water valve will be open in an intermediate position.

2) System of security management

The system of security management is made up of a system of presence control and of a system of security management.
The system of presence control is made up of:

- ✓ Sensor of access door opening
- ✓ Sensor of window opening
- ✓ Sensor of crystal breakage
- ✓ Sensor of access
- ✓ Simulation system
- ✓ MODEM
- ✓ Alarm

This system determines if somebody wanted to force a door to enter a certain space of the building or if somebody wanted to open a window with the same purpose.
In the same way, the system determines if somebody broke a window to enter or if the person who is entering a room is not authorized to do it.
The system of presence control operates in the following way: if somebody forced a door or a window, the corresponding sensor will be activated and the system sends a signal that will make sound an alarm and will activate a MODEM connected to the nearest police station.
The sensor of access control determines if the person who this entering the room is qualified for such situation; if not, the sensor is activated and will make sound an alarm to warn the security personnel of the building.
The system of security management is made up of:

- ✓ Sensor of water level
- ✓ Smoke Sensor
- ✓ Flame Sensor
- ✓ Gas Sensor
- ✓ Thermal Key
- ✓ Gas Electro valve
- ✓ Door Opening Controller
- ✓ Air Conditioner Controller
- ✓ Gas Electro valve
- ✓ Fire Extinguishing System
- ✓ Window Opening Controller
- ✓ MODEM

The system of security management operates in the following way: if in a certain room a fire is generated, the flame sensor and the smoke one will be activated and send a signal so that the gas electro valve is closed, deactivate the thermal key to cut power provision, the conditioned air is extinguished to avoid fire propagation and the MODEM is activated so that it makes a call to the nearest firemen station.
If a loss of gas exists, the sensor that measures the air composition will activate and send a signal so that the system closes the gas electro valve, opens the windows and doors and disconnects the thermal key.
If a loss of water in the building exists, the sensor that measures the water level will be activated, which will cause the water electro valve to be closed and the thermal key becomes disconnected to prevent possible risks in the people who occupy the building.

3) *System of power saving management*

The power saving management system is made up of:

- ✓ Clock
- ✓ Accumulation System
- ✓ Light system controller
- ✓ Thermal key switch
- ✓ Heating System switch

Power saving management system operates in the following way: the accumulation system is made up of a bank of batteries that loads in the morning between one and seven hour when the charge for energy by the electrical company is lowest. The rest of the day the accumulation system is used to activate the electrical system and to warm up the hot water tank that provides hot water to the whole building.

3. Implementation

The intelligent control program for a power efficient building has been designed using the software tool KAPPA-PC, specially oriented for the development of expert systems.

Figure 1 illustrates the initial screen of the application The following image, exhibited in figure 2, displays a view in plant of the building where it is shown the physical layout of the offices, the laboratory, the central hall, the office of computation and the machines room.

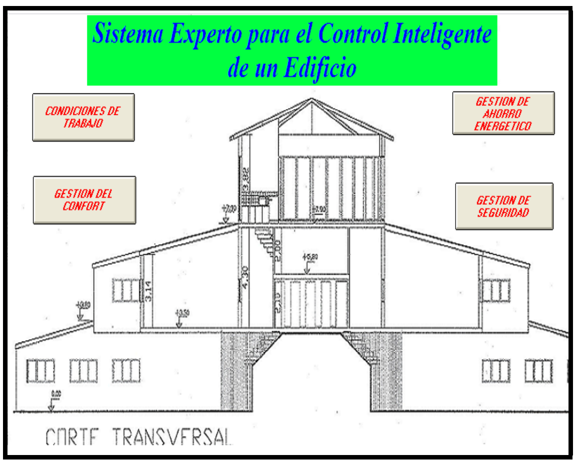

Fig. 1: Initial Screen for the Building Control System

The displayed image in figure 3 offers a representation of one of the laboratories of the building where it is shown the physical location of the sensor of natural light, of the sensor of artificial light, the sensor of presence and the sensor of temperature. In addition, it displays the buttons who allow the user to accede to the system of light, to the system of temperature control, to the system of security control and to the system of presence control. The screen exhibited in figure 3 also displays two access buttons access, one that allows to return to the previous image, that is to say, to the image of main view in plant of the building and the other button allows to return to the main image, that is to say, to the image that shows the main menu for building control.

3. Conclusions

The intelligent system that is presented in this article tries to contribute in the field of the optimization of intelligent buildings, transforming them into a dynamic space, with high standards of comfort and satisfaction for its occupants. In this sense, the inherent abilities of intelligent systems which are able to capture the knowledge of experts and to learn from its environment, plays a very important role in achievement of high optimization of the objectives. Therefore, future work of research and development in the field deserve particular attention.

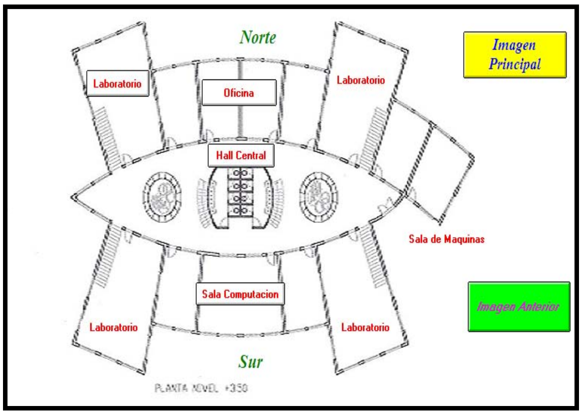

Fig. 2: Screen for access to different building spaces

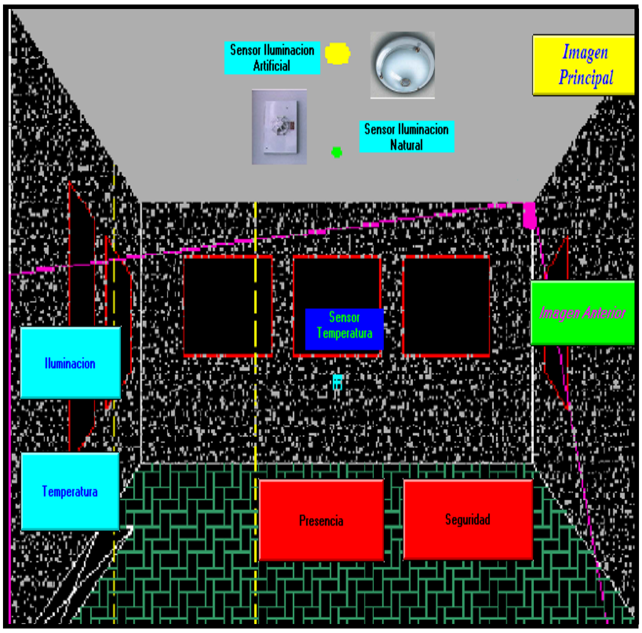

Fig. 3 Indication of sensors in labs

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