Automatic sensor arrangement system for building energy and environmental management

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Abstract

Building Energy Management System (BEMS) can save energy and minimize the impact on the environment due to energy efficiency technologies and systems. The most important thing of Building Energy Management is the monitoring of indoor environment in a building by various sensors such as temperature sensor, humidity sensor, illuminance sensor, motion sensor and CO2 sensor. We need to arrange environmental sensors automatically instead of manual disposition because it can save money and time, and display the disposition map of sensors in a monitor as a form of two dimensions or three dimensions. In this paper, we propose two types of automatic sensor arrangement system for building energy and environmental management which are automatic sensor arrangement system based on optimal disposition and automatic sensor arrangement system based on installation expenses, and explain each simulator algorithm and show arrangement positions of sensors in a designated room as a form of two dimensions.

Keywords: BEMS ; Automatic Sensor Arrangement System ; Optimal Disposition ; Installation Expenses-based Disposition

1. Introduction

Building Energy Management System (BEMS) is the major target area to save energy because buildings account for roughly 40 percent of all U.S. energy use and buildings account for about 24 percent of all Korea energy use [1].

A BEMS is similar to a traditional Building Management System (BMS), but it is brought to market by vendors that focus on energy efficiency and energy management. A BEMS consists of three components which are building automation and control, energy efficiency technologies and systems and demand response systems [2].

The most important thing of Building Energy Management is the monitoring of indoor environment in a building by various sensors. Environmental sensors of BEMS are temperature sensor, humidity sensor, illuminance sensor, motion sensor, CO2 (carbon dioxide) sensor, etc. We need to arrange environmental sensors according to the size and the shape of room or corridor in building to measure various environmental conditions. Until now almost sensors for BEMS were arranged manually and empirically. We need to arrange sensors automatically because it can save money and time, and display the disposition

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map of sensors in a monitor as a form of two dimensions or three dimensions. We’ve developed automatic sensor arrangement system for building energy and environmental management. Our automatic sensor arrangement system consists of two types of simulators such as optimal simulator and simulator based on installation expenses.

In this paper, we propose two types of automatic sensor arrangement system for building energy and environmental management. This paper is organized as follows. In Section 2, we describe the automatic sensor arrangement system based on optimal disposition for building energy and environmental management. In Section 3, we explain the automatic sensor arrangement system based on installation expenses for building energy and environmental management. Finally, we conclude this paper in Section 4.

2. Automatic sensor arrangement system based on optimal disposition for building energy and environmental management

In order to implement the BEMS infrastructure automatically, we designed an automatic sensor arrangement system based on optimal disposition for building energy and environmental management. Figure 2 shows the block diagram of the automatic sensor arrangement system based on optimal disposition for building energy and environmental management. In Figure 2, Building/floor/room/corridor DB stores building/floor/room/corridor information from user input. Sensor selector selects the kind of sensor of a designated room or corridor for automatic arrangement based on optimal disposition. Optimal simulator for each kind of sensor calculates the optimal quantity based on the optimal basic space, finds the optimal arrangement coordinates and calculates the optimal total expenses. 2D/3D display for each kind of sensor shows the optimal arrangement positions of sensors in a designated room or corridor as a form of two dimensions or three dimensions.

2.1. Temperature sensor optimal simulator

We designed a temperature sensor optimal simulator as a component of an automatic sensor arrangement system based on optimal disposition for building energy and environmental management.
Figure 3 shows the block diagram of the temperature sensor optimal simulator. In Figure 3, Temperature sensor optimal basic space module decides the optimal basic space as \( a_1 \) m\(^2\) in terms of measurement precision and installation expenses, for example \( a_1 = 100 \) and it can be changeable. Temperature sensor optimal quantity module calculates \( QO(T) \) which is temperature sensor optimal quantity. Equation (1) shows \( QO(T) \).

\[
QO(T) = \text{int}(\frac{ST + a_1}{a_1}), \ ST = \text{horizontal dimension of a room or a corridor} \tag{1}
\]

Temperature sensor optimal arrangement module finds \( PO(T) \) which are temperature sensor optimal arrangement coordinates according to an ASHRAE Standard [3]. Equation (2) shows horizontal \( PO(T) \) and Equation (3) shows vertical \( PO(T) \).

\[
\text{Horizontal } PO(T) = \frac{i}{(QO(T) + 1)} \times LCD, \ LCD = \text{longer central distance of a room or a corridor},
\]

\[
\text{Vertical } PO(T) = \frac{j}{(QO(T) + 1)} \times LCD
\]
\[ i = \text{integers from 1 to } QO(T), \]

Vertical PO(T) = 0.1, 0.6, and 1.1 m levels above floor for sedentary occupants,

or 0.1, 1.1, and 1.7m levels above floor for standing occupants, \[ \text{(3)} \]

Temperature sensor unit expense module decides the unit expense as \( a_2 \) dollars in terms of actual cost, for example \( a_2 \) is 125 and it can be changeable. Temperature sensor optimal total expenses module calculates COT(T) which is optimal total expenses. Equation (4) shows COT(T).

\[ COT(T) = a_2 \times QO(T) \times 3 \quad \text{(4)} \]

2.2. Optimal simulators of motion, humidity, illuminance and CO2 sensor

Motion sensor optimal simulator is the same as temperature sensor optimal simulator except that optimal basic space(b1) is 144, horizontal PO(M) which are motion sensor optimal arrangement coordinates are the centers of each square of 12 m x 12 m firstly, the centers of each rectangle of length of 12 m secondly and the center of remaining space lastly, vertical PO(M) are the ceilings at the locations specified in horizontal PO(M), motion sensor unit expense(b2) is 200 and it can be changeable, and motion sensor optimal total expenses module calculates COT(M) which is optimal total expenses. Equation (5) shows COT(M).

\[ COT(M) = b_2 \times QO(M) \quad \text{(5)} \]

Humidity sensor optimal simulator and CO2 sensor optimal simulator are the same as temperature sensor optimal simulator except that humidity sensor unit expense and CO2 sensor unit expense are different from temperature sensor unit expense. Illuminance sensor optimal simulator is the same as motion sensor optimal simulator except that vertical coordinates of illuminance sensors are 1.5 m levels above floor at the locations specified in horizontal PO(L).

3. Automatic sensor arrangement system based on installation expenses for building energy and environmental management

In order to implement the BEMS infrastructure automatically, we designed another automatic sensor arrangement system based on installation expenses for building energy and environmental management. Figure 4 shows the block diagram of the automatic sensor arrangement system based on installation expenses for building energy and environmental management. In Figure 4, Building/floor/room/corridor/installation expenses DB stores building/floor/room/corridor/installation expenses information from user input. Sensor selector selects the kind of sensor of a designated room or corridor for automatic arrangement based on installation expenses. Simulator based on installation expenses for each kind of sensor calculates the quantity and the basic space according to the installation expenses and the unit expense, and finds the optimal arrangement coordinates. 2D/3D display for each kind of sensor shows the arrangement positions based on installation expenses of sensors in a designated room or corridor as a form of two dimensions or three dimensions.
3.1. Temperature sensor simulator based on installation expenses

We designed a temperature sensor simulator based on installation expenses as a component of an automatic sensor arrangement system based on installation expenses for building energy and environmental management. Figure 5 shows the block diagram of the temperature sensor simulator based on installation expenses. In Figure 5, Temperature sensor installation expenses module stores CPT(T) which is the installation expenses of temperature sensor of a designated room or corridor from user input. Temperature sensor unit expense module decides the unit expense as $a_2$ dollars in terms of actual cost, for example $a_2$ is 125 and it can be changeable. Temperature sensor quantity based on installation expenses module calculates QP(T) which is temperature sensor quantity based on installation. Equation (6) shows QP(T).

\[ QP(T) = \frac{CPT(T)}{a_2} \quad (6) \]

Temperature sensor basic space based on installation expenses module calculates SP(T) which is temperature sensor basic space based on installation expenses. Equation (7) shows SP(T).

\[ SP(T) = \frac{ST}{QP(T)}, \ ST = \text{horizontal dimension of a room or a corridor} \quad (7) \]

Temperature sensor arrangement based on installation expenses module finds PP(T) which are temperature sensor arrangement coordinates based on installation expenses according to SP(T). Equation (8) shows horizontal PP(T) and Equation (9) shows vertical PP(T).

Horizontal \[ PP(T) = \text{centers of each space of SP(T)} \quad (8) \]

Vertical \[ PP(T) = 1.1 \text{ m level above floor for sedentary occupants,} \]

or \[ 1.7 \text{m level above floor for standing occupants}, \quad (9) \]
3.2. Simulators based on installation expenses of motion, humidity, illuminance and CO2 sensor

Motion sensor simulator based on installation expenses, humidity sensor simulator based on installation expenses, illuminance sensor simulator based on installation expenses and CO2 sensor simulator based on installation expenses are the same as temperature sensor simulator based on installation expenses except that their unit expenses are different from temperature sensor unit expense, vertical coordinates of motion sensors are the ceiling at the locations specified in horizontal PP(M) which are motion sensor arrangement coordinates based on installation expenses, and vertical coordinates of illuminance sensors are 1.5 m levels above floor at the locations specified in horizontal PP(L) which are illuminance sensor arrangement coordinates based on installation expenses.

4. Conclusion

In this paper, we proposed two types of automatic sensor arrangement system for building energy and environmental management which are automatic sensor arrangement system based on optimal disposition and automatic sensor arrangement system based on installation expenses, and explained each simulator algorithm of temperature sensor, humidity sensor, illuminance sensor, motion sensor and CO2 sensor.

The automatic sensor arrangement system proposed in this paper can be applied to the installation of environmental sensors in a building. Further study on the three dimensional automatic sensor arrangement system using the technology of Building Information Modeling (BIM) and Industry Foundation Classes (IFC) is needed.

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