An Integrated Approach to the Visualization of Indoor Temperature Changes on the Floor Plans

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Abstract -

This paper aims to develop a mechanism for visualizing indoor environment data set sensed by diverse sensors. The focus of this research is the development of an integrated visualization process using accumulated data from sensors, rather than the qualitative analysis of indoor environment. In this regard, we use a test-purposed and versatile toolkit that is cheaper, smaller and more controllable than conventional tools. We could collect indoor environmental data set composed of sequential numeric data so as to use them as a given parameters for visualization. We inspected three major issues in the process: 1) indoor temperature data of a specific room can be collected at a second interval; 2) such a data set can be varied by subdivided spots of interest using multiple toolkits; 3) as a result, the collection of data is regarded as one type of parameters for visualization on top of the room's floor plan, e.g. a sudden change of sequential numbers. The toolkit and control mechanism described in this paper can be summarized as following modules: 1) the sensor module; 2) the data collection module; 3) the data retrieval module; 4) the spatial data module; 5) the sensor location module; 6) the data visualization module. A demonstration has been introduced in this paper for evaluating the integrated visualization approach.

Keywords -

Sensed data, Numeric data, Parameters for visualization, Indoor temperature changes

1 Introduction

People spend most of their daily lives indoor, and this simply explains why indoor temperature is one of the important factors to deal with as an environmental aspects [1, 2]. Therefore controlling comfortable indoor condition is essential for the people to keep their emotional and physical states healthy. This may be resulted in better work productivity [3, 4]. For dealing with further issues of the physical environment, this paper aims to figure out an integrated approach to visualize such conditional factors using indoor temperature changes. The baseline of this approach is to measure the temperature and analyze given conditions [5].

Conventionally, to measure and collect the indoor environmental data such as temperature data set used to be inconvenient and expensive due to several reasons [6]. The multi-use environmental sensors, however, became affordable and easy to control recently, and this enabled us to measure the broad range of indoor environments by using such low-priced and controllable sensor devices [7]. In the meantime, as the data set acquired by widely installed environmental sensors increased significantly, the need for making effective use of the data has become of importance [8, 9, 10].

An integrated approach and mechanism to visualize indoor environmental data on the floor plan is introduced as an effective method for analyzing the data of indoor environment. Consequently, to verify the feasibility of the proposed mechanism in this paper, we implemented an integrated approach to the visualization of indoor temperature changes using several software and hardware modules.

2 Scope and Approach

We reviewed several research using the sensor to manage indoor environment and found out that those focus on representing sensed data as the chart [11, 12, 13, 14].

This paper aims to demonstrate a specific visualization mechanism on top of the floor plans based on the sensed changes of indoor temperature as one of the indoor environmental data sets. This is one of the graphical representations on the existing building geometry using sensor devices and sequential processing mechanism. The entire process from sensing indoor environment to processing and visualizing acquired data can be subdivided into three parts. Each part is composed of sub-modules. Figure 1 shows the parts and included modules of this research and development.

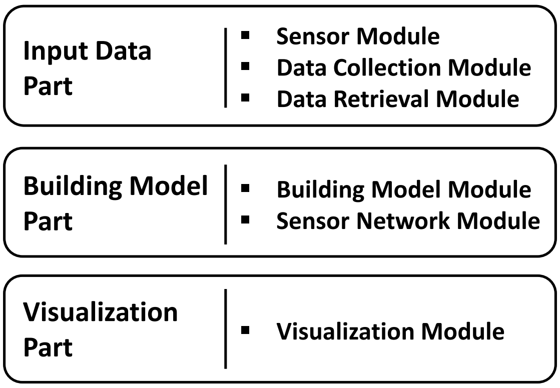

Figure 1. Three major parts of the implementation and demonstration depicted in this paper.

After dealing with the three parts of visualization process and the functions of each module inside, this paper will conduct a demonstration on an actual space. The target environment element to be visualized is hourly variation of temperature change.

3 System Architecture

The system architecture for visualizing the indoor environment is composed of three parts. 1) Building model part, 2) Input data part, and 3) Visualization part.

In the building model part, as it literally means, the 2D floor plan or 3D building model which is the background for visualization is loaded. Also, all the influence factors of target environment and the reference point of the installed sensors in the building model should be included for the more accurate analysis. The input data part deals with the environment data. In this stage, the environment data are sensed by installed sensors and collected, retrieved, and processed in order to generate the data to be visualized. The outcome data generated in the Input data part are transferred to an infographic and combined with loaded building model in Visualization part.

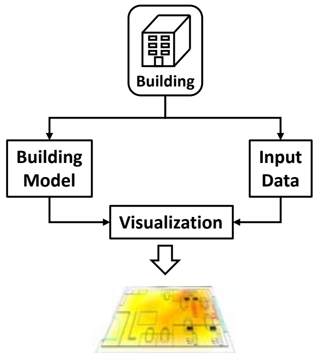

Figure 2. Overview of the System Architecture for the Visualization of Indoor Temperature Changes

4 Implementation

The data flow during the entire visualization process is summarized in Figure 3. Input Data Part is composed of three modules: 1) Sensor Module, 2) Data Collection Module, and 3) Data Retrieval Module. These three modules measure the target environmental element and generate the outcome data to be visualized.

The Building Model Part consists of two modules: 1) Building Model Module, and 2) Sensor Network Module. The Building Model Part loads the building model such as 2D floor plans or 3D building model and determine the reference point of installed sensors. The input data and loaded building model are combined by Visualization Module in Visualization Part.

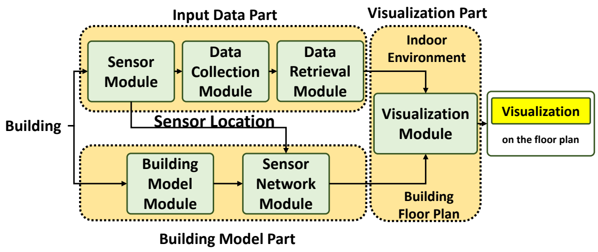

Figure 3. Data flow diagram of the six major modules of implementation.

4.1 Input Data Part

4.1.1 Sensor Module

The Sensor Module measures the target indoor environment by multiple sensors and generates sets of raw data. Each sensor senses the numeric value of target indoor environment at an interval of time, and the data are collected into a set of raw data in the Data Collection

Module. Generating enough number of datasets by installing enough number of sensors is important because the more input data makes the more precise and broader visualization outcome.

There are various kinds of target indoor environment can be measured such as temperature, humidity, brightness, air quality, movement, etc. In this paper, temperature is the target indoor environment to be visualized.

4.1.2 Data Collection Module

The Data Collection Module collects the target environment data measured by Sensor Module. In this module, the data sensed by installed sensors each time are accumulated in real time.

Depending on the compatibility between the installed sensors and visualization software, there are two possible methods to collect data. In case the sensors are compatible with Visualization s/w, the data are able to be collected directly on the Visualization s/w. Otherwise, if the sensor is incompatible with Visualization s/w, the collected data should be transferred to a suitable format which is compatible with Visualization s/w such as csv, DB, Excel file.

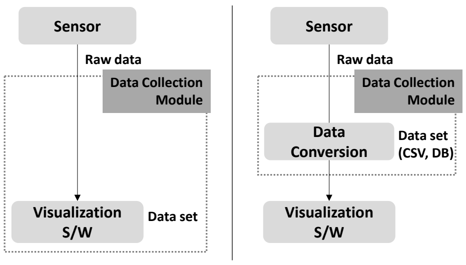

Figure 4. The role of Data Collection module: without data conversion (left) and with data conversion (right)

4.1.3 Data Retrieval Module

The Data Retrieval Module selects particular part of data among the collected raw dataset in order to generate input data. But before selecting particular part of data, defining the input data should be preceded. Depending on the definition of input data, the target and algorithm for data retrieval are decided.

Not only selecting particular part of data from dataset of measured environment data, it is also possible to decide what environment element to visualize when there are plural indoor environment elements collected by installed sensors.

4.2 Building Model Part

4.2.1 Building Model Module

The Building Model Module loads the building geometry which becomes a back-layer of the visualization. The loaded building model is used as reference for designating the boundary of sensor network layer and analyzing visualization outcome.

The use of loaded building model regarding designation of the boundary of sensor network layer is described on the Sensor Network Module. When the building model is combined with the visualization outcome, the building model becomes the basis of analysis of the visualized indoor environment data. To do that, the building model should include all the factors that influence the target indoor environment within the space.

4.2.2 Sensor Network Module

The Sensor Network Module generates the sensor network layer which becomes the basis for visualization on building model. Based on the loaded building model, the shape and the size of boundaries of the sensor network layer are defined. The generated sensor network layer will be visualized in Visualization Module, being mapped with the input data processed by Data Retrieval Module. Each sensor location, which is going to be mapped with the input data, is able to be acquired by IPS (Indoor Positioning System). There are several possible IPS system like using Wi-Fi, GPS antenna, Geo-Magnetism. Without IPS, the sensor location can be designated manually comparing given building model with the sensor location in actual space.

4.3 Visualization Part

4.3.1 Visualization Module

Visualization Module transforms the numeric input data into visual information using sensor network layer. Each input data of an installed sensor is connected to each sensor points on the sensor network layer. Connected with the input data, the sensor points can be expressed in any type of graphical image including color or geometry. In this step, the visualization method is decided depending on the building model and the definition of input data, considering how to visualize the interested environment data in the most intuitive way. When the visualization method is decided and the input data is connected to each sensor points, the sensor network layer transforms to a certain form of visual information, according to the decided visualization method and the retrieved input data.

5 Demonstration

We have demonstrated an integrated approach for visualizing the indoor temperature changes of a laboratory room located in building of College of Human Ecology, Hanyang University to examine feasibility of proposed mechanism.

Figure 5 represents the overall flow of the demonstration including the software/hardware used in each stage.

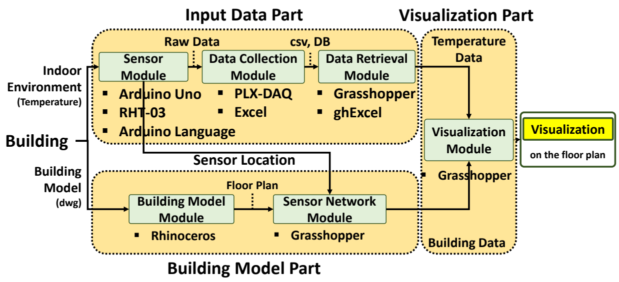

Figure 5. The data flow and software/hardware used in each module.

5.1 Input Data Part

5.1.1 Measurement of Temperature

Arduino Uno Board and RHT03 sensors were used as instruments measuring the temperature, which are cheap and easy to control. RHT03 is a penny-sized temperature/humidity sensor which is enable to measure from -40 to 80 degrees C temperature range and also has +/- 2% error range in humidity [15]. Arduino Uno Board is a microcontroller board controlled by Arduino Language [16]. Using the language, it is possible to control how the sensors operate and in what form the data will be collected. In this paper, the sensors operated with 60 seconds interval and temperature was collected as Celsius degree.

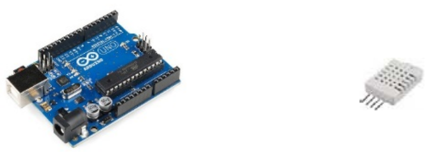

Figure 6. Arduino Uno Board (left) and RHT03 sensor (right)

5.1.2 Converting and Collecting the Measured Data

The measured environment data was collected in an Excel spreadsheet due to the issue of compatibility with Rhino-Grasshopper on which the environment data will be visualized. An Excel plug-in software named PLX-DAQ (Parallax Data Acquisition tool) was used for exporting the measured data from the Sensor Module into an Excel file [17].

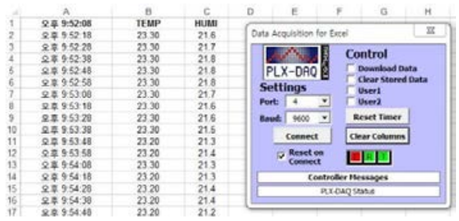

Figure 7. Exporting the measured data into Excel spreadsheet file using PLX-DAQ plug-in.

Each dataset measured by the sensors is collected in each spreadsheet and a dataset includes temperature, humidity and the time the sensor operated.

5.1.3 Temperature change Data Retrieval

The implementation stages between data retrieval and visualization have been implemented using Rhino-Grasshopper in this demo. The Grasshopper is compatible with Excel spreadsheet file using a plug-in program named ghExcel[18]. The datasets consist of time, humidity and temperature values in 60 seconds interval and the target environment element is temperature.

In order to generate the final input data from collected datasets, the input data need to be defined before selecting particular part of data. The input data was defined as the subtraction of two temperature value between two moments at an hour interval. As one interested moment is selected, the temperature values of the selected moment and 1 hour later are retrieved. After retrieving two temperature values to be compared, the temperature difference is generated for the final input data. This demo used Rhino-Grasshopper “slider” function for selecting interface for retrieval.

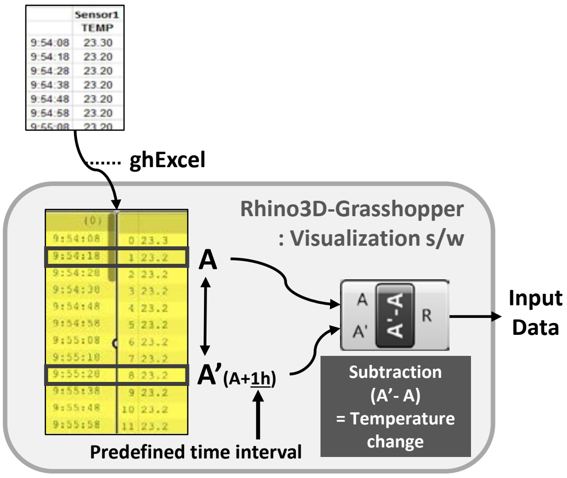

Figure 8. Generating temperature change data by the Data Retrieval Module

5.2 Building Model Part

5.2.1 Importing Floor Plan

As the building model for this demo, the floor plan is imported to rhino 3D. The size and layout of the space are shown in figure 9. In addition for the sensors and all the factors affecting temperature such as heaters or openings are expressed too.

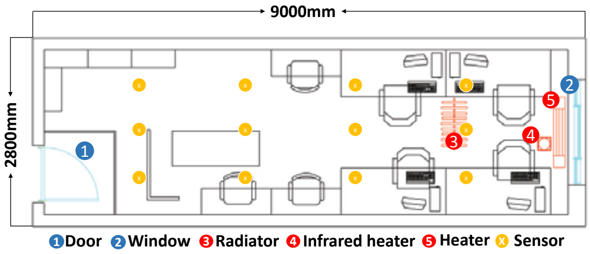

Figure 9. An actual floor plan for the demonstration

5.2.2 Generating Sensor Network Layer

Previous to the visualization stage, sensor network layer has been made above the floor plan. The sensor network layer becomes the basis when transferring the input data into visual information. Pointing at the corners of the floor plan's outline, the boundary of sensor network layer was defined. On the boundary of layer, each sensor points were created on each sensor location. The sensor points were designated on the layer manually based on the comparison of floor plan with the actual space, because IPS, by which the sensor location is acquired, is not used in this demo.

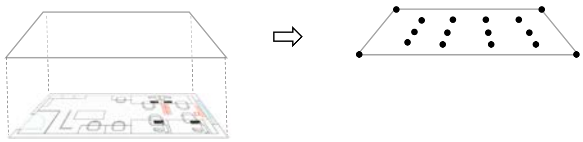

Figure10.Generation of Sensor Network Layer

5.3 Visualization Part

5.3.1 Visualizing Input Data

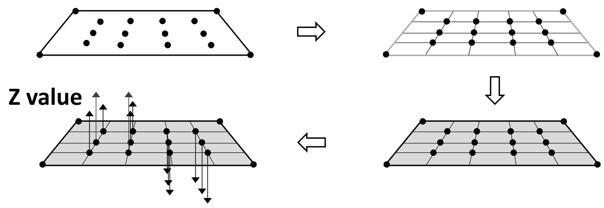

Figure11. Process of generating geometry using grid segments

For the visualization of given input data above it, the sensor network layer is divided into grid segments with each sensor point as the center. The divided layer forms a flat surface which is able to be connected with the input data on each sensor point. The given input data are assigned to each sensor point as z value of Rhino3D. As the sensor points move to the z axis direction, the surface is transformed to an uneven surface.

At the same time, it is possible to express the temperature change as color as well as the geometry. As shown in figure 12, according to the distance to the floor plan the surface is colored with red-to-blue color gradation. As a result, input data assigned as z value are transformed into visual information like geometry, color.

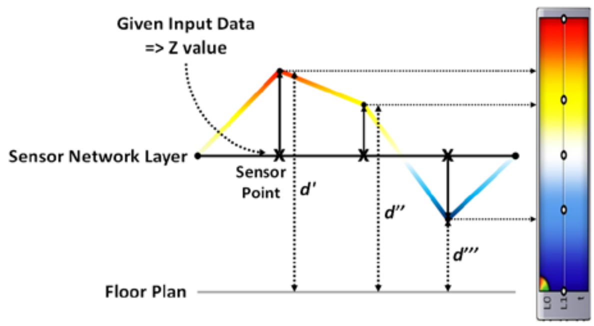

Figure 12. Visualization mechanism of converting z value to color gradation

5.4 Result and Analysis

Figure 13 shows the final visualization outcome on Rhinoceros3D viewport. In top view the temperature changes is shown as colors overlapped on the floor plan. In this way it is easier to realize the state of indoor environment and factors to influence the temperature changes. In isometric view, the degree of temperature changes appears in the form of geometry which looks like a colored uneven plane. The three-dimensional visualization of an indoor environment element is very intuitive compared to two-dimensional or numeric information.

The input data of the left visualization result is the temperature changes between 9am ~ 10am. The outcome shows that the overall temperature has been raised centrally around the heater. On the contrary, the input data of right visualization result is the temperature changes between 9pm ~ 10pm. The temperature decreased rapidly during 1 hour with the heater and window as center because the heater was turned off and the window was opened.

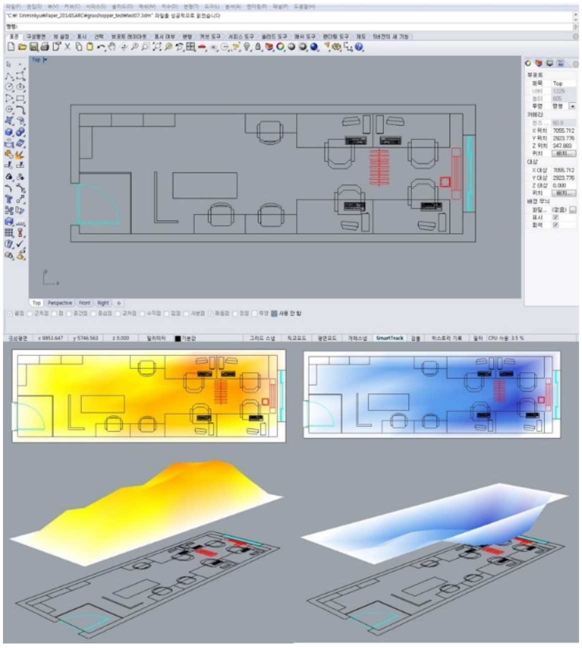

Figure13. Result of Temperature changes Visualization

6 Summary

This paper introduces and demonstrates an integrated approach for visualizing the indoor environment on the floor plan with an actual test case. The entire system consists of three major parts, which are able to be subdivided into 6 modules. As shown in Section 5Demonstration, which is visualizing temperature changes in a position for an hour, visualization mechanism proposed in this paper enables to process the numeric data and to convert processed data into visualized data.

As a result, we find out that the visualized environmental data are more intuitive and easier to figure out state of indoor environment than numeric data. Combined with the building model, in addition, the visualized data can be used for recognition of the factors affecting to target environmental element. To visualize not only temperature changes but also other indoor environment, we need to develop the visualization mechanism, considering various kinds of available sensors, their network and visualization methods.

Acknowledgment

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