PROCESSING AND VISUALIZATION OF MICROCLIMATIC DATA BY USING VIRTUAL REALITY

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The appropriate way of measured data visualization is an important factor which has a significant impact to its quality as well as to the speed of the data analysis. Especially when the analysis is carried out by a multidisciplinary team. The virtual reality is one of the techniques used for data visualization. It is progressive technology which enables better and faster understanding to visualized data. In this paper it is described a platform based on the database system for a data combined with their representation in virtual reality. The platform is designed for storing and visualization of microclimatic data from indoor spaces and climatic data from corresponding outdoor locations. Measured data are transmitted over the Internet to the database and they are visualized by an application which is created using Unity 3D engine. The resulting application is suitable as a tool for monitoring and direct regulation of internal microclimate by user.

KEYWORDS

virtual reality, virtual environment, database system, visualization, microclimatic data

1 INTRODUCTION

Nowadays, huge amount of data is being collected. It is necessary to analyze them and give meaning to the results. At the same time the data interpretation and presentation to the wider public seems as problematic as it places high demands on the knowledge of the subject and the spatial imagination of the observer. For these reasons, virtual reality is a way to visualize and facilitate understanding of the data analysis results.

Important issue in civil engineering is to improve internal microclimate of apartment buildings after refurbishment [Dolezilkova 2006]. With new tight building envelope, it is necessary to change inhabitants thinking about how to behave with home heating and air-conditioning. This contribution shows one of the possible ways how to solve this problem.

2 USING OF VIRTUAL REALITY FOR VISUALIZATION OF DATA

Nowadays, science and engineering produce large data amount. The size of these data can reach terabytes or even petabytes [van Dam 2002]. For this reason, it is necessary to create new technologies for their processing. Virtual reality provides a powerful and innovative tool for multi-dimensional data visualization [Donalek 2014]. A 3D stereo projection and an immersion have significant influence for understanding of data visualization. This is the reason for using a virtual reality for data visualization in different branches like industry [Cheng 2013], medicine [Kersten-Oertel 2013] or science [Bilke 2014]. VR is suitable especially for visualization of volume data, which is an important tool for datasets analysis e.g. 3D medical images, seismic data or paleontological data [Laha 2012]. V-Scope is an example of volume visualization system which allows clinicians and researchers to investigate 3D imaging data [Koning 2009].

Virtual reality is used in the field of industry especially in automotive. Automobile manufactures use VR for evaluation of car design during an early stage of development process [Lawson 2016]. VR is also mentioned with new trend in manufacturing technologies Industry 4.0. Industry 4.0 deals with integration of information and communication technologies and industrial technology [Zhou 2016]. Industry 4.0 is based on the Cyber-Physical Systems (CPS) which are automated systems used for interconnecting a real and virtual world [Jazdi 2014]. In this case VR can be used for visualization of assembled dynamic virtual models or simulation results [Augste 2013, Kovar 2016].

From the scientific point of view, VR can be a useful for collaborative data visualization. It provides an easy and native path to exploration of multi-dimensional data with colleagues in the same visual space. This approach makes data more intuitive to understand and keeps a better retention of the data perceived relationships [Donalek 2014].

3 INTERNAL MICROCLIMATE PARAMETERS

An objective evaluation of the internal environment is provided by measuring of selected physical quantities. For the given application, three commonly measurable parameters are selected for internal microclimate evaluation, these are indoor air temperature, relative humidity and carbon dioxide concentration. These selected parameters influence in a fundamental way quality of thermo-humidity component and of the odorous (or even toxic) component of internal microclimate [Kotek 2015]. Temperature and relative humidity are selected because they can be relatively easily changed by adjusting the heating or ventilation. CO_2 concentration is selected because it is often possible to ensure compliance with the limits for other odorous compounds that are more difficult to measure by complying with established limits of CO_2 concentration in the air.

Individual effects of selected parameters on human health are discussed further. Blood flow to the peripheral parts of the body is limited in cold environment due to defensive human thermoregulation. As the next phase direct heat production can be reduced in cold environment and person is experiencing muscle tremors. At low humidity, the dustiness and spread of allergens increases. Possible carbon dioxide concentration for old buildings is from 350 ppm to 1150 ppm according to EN 15251. With increased concentration of carbon dioxide there are signs of fatigue, decreased concentration on the activity, increasing hearth rate until the loss of consciousness. From the value 2000 ppm it is leading to headache, over 5000 ppm person can feel sick.

On the base of data from internal microclimate measurements it is possible to warn the user and consequently to give advice. The individual warning settings are summarized in Tab. 1.

When the average air temperature during the day in three consecutive days equals or is lower than 13 °C it is considered for the beginning of the cold season. Switching to another period of the year is automated according to the data from the meteorological station database.

	Year season	Temperature [°C]	Humidity [%]	CO_2 [ppm]
Optimal setting	Hot	22 ~ 26	35 ~ 60	350 ~ 1000
	Cold	20 ~ 24		
Warning	Hot	> 26	≥ 60	≥ 1150
	Cold	< 20; >24	≤ 35	
Warning about limit exceeding		< 16; > 28	≤ 30; ≥ 65	≥ 1500

Table 1. Input values for internal microclimate as defined by standard EN15251

4 DATABASE SYSTEM AND VR APPLICATION DESIGN

The main aim of this paper is design and implementation of database system for storing microclimatic data from indoor space as well as corresponding outdoor climatic data from that location. The database system is connected with virtual environment for the data visualization purposes. Major motivation for this project is to ensure better understanding to measured data. Before the concept design several objectives are specified:

- Design of appropriate database structure for microclimatic and climatic data storage
- Design of virtual environment for data interpretation
- Visualization of microclimatic and climatic data in virtual environment
- Warning to microclimatic data limit exceeding in virtual environment

4.1 VR Hardware and development environment

Many VR platforms provide a multi user collaboration experience in virtual environment such as CAVE, PowerWall or head-mounted displays (HMD) like Oculus Rift or HTC Vive.

These devices differ of degree in immersion as well as in acquisition and maintenance costs. VR platforms are divided into full-immersive devices such as CAVE and HMDs and semi-immersive device such as PowerWall or monocular head-based VR devices. From the acquisition and maintenance costs viewpoint, CAVE and PowerWall are the most expensive VR solutions. The cost of these solutions is high due to the use of several projectors for stereo projection powered by cluster of computers. On the other hand, there are HMDs which have relatively low acquisition and almost no maintenance costs. However, HMDs provide lower display quality, limited field of view and are less ergonomic in comparison to CAVE.

The HMD Oculus Rift is chosen on the base of set objectives and the above-mentioned knowledge. HMD is used together with the Oculus Touch for more comfortable operation.

There are three options for VR Oculus Rift application development: Unity3D, Unreal Engine and PC SDK. Unity3D and Unreal Engine are game engines which include Oculus plugin. The main advantage of these engines is easy creating of VR application with already implemented functionality (e.g. physics engine). These two engines mainly differ in their programming languages support. Unreal engine uses C++ and Unity3D uses C# or JavaScript. The last additional option is to use PC SDK for own VR application development in C++. Main requirements for development environment are:
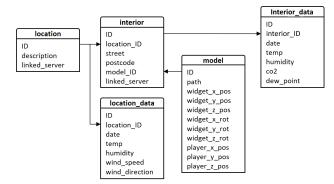
- Free license
- Support of C# scripting
- Easy creation of VR applications

Due to above mentioned reasons Unity3D is chosen as the main development environment.

4.2 Data Storage

The database server powered by Microsoft SQL Server is used for storage of data measurement. Designed database has to be able to store microclimatic data from indoor spaces as well as climatic data from corresponding locations. Easy manipulation with the data, redundancy prevention and better data consistency are required. In order to achieve these attributes, the first, the second and the third normal forms of database normalization are used. The design structure of tables for data storing is shown in Fig. 1. The database contains five tables. Table names and their functions are followings:

- location - contains description about the location of the meteorological station and the name of the linked server with data from the station
- location_data - contains measured data from the specific meteorological stations
- interior - contains the address of each interior, the location ID of situated position and the linked server to the database with measured data from the flat
- interior_data – contains the measured data from interiors
- model - contains the path to model of the room, the position, the rotation of the information panel and the camera position on the room

Figure 1. The database structure is composed of five tables. Relationships between them are figured by the arrows

The standalone database server is used in order to able run application on other computers with no need to install and configure a database system. The data from database are obtained by the ASP.NET services which are located together with database on the same server. ASP.NET services provide public methods for execution SQL queries and stored procedures on the database. The communication scheme of application, ASP.NET services and database is shown in Fig. 2.
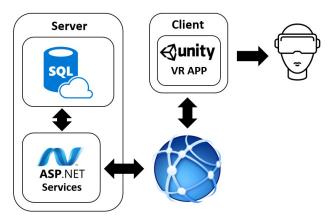
Figure 2. Communication between server and client station is based on the ASP.Net services through WAN or LAN.

4.3 VR Application

The main points of the VR application are user interface, virtual environment and data visualization.

4.3.1 User interface

Unity3D UI system is used for user interaction in VR application. This system contains basic UI elements like button, input field, text, image, etc. Based on these UI elements, floating menu is created for application control. The interaction with UI elements is solved by using pointer which is moved over the world-space plane. This pointer is operated by Oculus Touch controllers. The main menu contains player bar and 'Calendar', 'Clock', 'Change Room' and 'Close' buttons. The function of these buttons follows from their names.

The first two buttons are used for setting the date and time of data record. Menu for date change is designed in a form of calendar. Fast switching between months is possible by clicking on the name of the month in calendar header. By the choice of specific day, the time setting is displayed. After the time confirmation the corresponding data record is loaded from database.

The 'Change Room' button is used for changing measurement location. When the button is pressed the dynamic menu with list of location names appears. Last button is used for closing the menu.

The player bar contains three buttons. The buttons 'step backwards' and 'step forwards' are used for quick switching to the next or the previous record. The 'play/stop' button starts or stops displaying data records sequence.

4.3.2 Virtual environment

Data are visualized in 3D environment model of the same interior where the data are measured. Application contains any number of 3D environment models because microclimatic data can be measured in different indoor spaces. These models are stored in 'Resources' directory in Unity3D project. The file paths of these models are stored in the database table 'model'. When the place of measured data is chosen, the file path of model is loaded from database and the model is instantiated on the scene.

It is not possible to use default camera position for all 3D environment models because each of them has a different geometry or contains different objects. For this reason, the position needs to be edited. Therefore, the modified position for each model is stored in the database table 'model'.

4.3.3 Data visualization

The measured data are visualized on the information panel which contains all requirement information such as temperature, humidity, CO2 concentration, etc. Design of this information panel is shown in Fig. 3. Its position and rotation in

space is stored in database table 'model'. This information is loaded together with file path of the model. Position and rotation are set before 3D environment model of indoor space insertion into scene.

The system for warning visualization to microclimatic data limits is implemented as well. User is informed about value limit exceeding by changing the text color of corresponding value on information panel. User also receives information about recommended action which guarantees improve of microclimatic condition. For example, when the indoor temperature is high and outdoor temperature is below limit value, model of window in virtual environment starts blinking red which signalizes notification to open the window. Tab. 1 summarizes all conditions and types of notifications which are implemented.
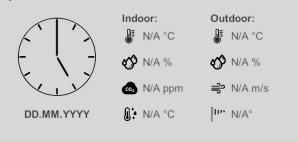

Figure 3. Panel where information about microclimatic and climatic data are displayed

5 CONCLUSIONS

The main aim of this paper was design of database system for storing microclimatic and climatic data together and design of VR application for their visualization. Designed database system was developed based on Microsoft SQL Server and was normalized by the first, the second and the third normal forms. This solution guarantees easy manipulation with data, redundancy prevention as well as better data consistency. For the data access ASP.NET services were created. These services provide execution stored procedures and SQL queries and they were located on the same computer as the database server. The simple VR application for demonstration of measurement data visualization was created in Unity3D engine. Measured data is visualized in virtual environment which is represented by real interior space where the data were measured. The application contains user interface which enables switching between measurement data locations and data records. These data are loaded from the database by using ASP.NET services and they are visualized on information panel. Notification about corresponding action is displayed after the limit exceeding of individual measured value. The application is designed for a better understanding of internal microclimate and its suitable for direct monitoring and regulation by the user. Application follows the newest trends in mechanical and civil engineering. In the future work the solution will be used for visualization of operational data such as temperature, vibrations, etc. in the virtual environment.

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