Title:
Visualisation and Simulation of Environmental Factors Analysis in Virtual Reality

Authors:
Wael Abdelhameed, wael.abdelhameed@gmail.com, wabdlehameed@uob.edu.bh, University of Bahrain

Keywords:
Environmental Analysis Simulation, Microsimulation, Virtual Reality

DOI: 10.14733/cadconfP.2017.143-148

Introduction:
Architectural design is to conduct creative cognitive activities through which architects attempt at fulfilling different needs, factors and variables such as functional, social, aesthetical, structural and technical, in order to design a building for humans with a specific function. Including environmental factors impact on building-design performance in the initial phases of designing would have a positive result on the final building performance. Many of the environmental factors can improve this performance noticeably by passive solutions, i.e. designing only [6],[5],[4],[3], without seeking active solutions such as using insulation materials of different types. On the other side, considering the analysis of those environmental factors at later design stages after form is fully created would lead to more cost, time and effort. To conduct several environmental factors analysis of the building, to create simulations of the analysis and to visualize the results during the designing phases would effectively help architects and the design team not only communicate in a better way but also improve the design output.

In architectural design, achieving sustainability through its main areas: society, economy and ecology, is an important design objective. Sustainable design aims at achieving positive building performance in regard to environmental factors in general, and the comfort of building occupants in particular. The concern of this paper is the environmental factors and their analysis such as: thermal, solar, acoustic, daylighting and ventilation and air flow.

Paper Objective:
Environmental factors analysis helps measure their impact on building performance in various areas such as: energy saving, thermal, solar, day lighting, acoustic and ventilation and air flow. The perception and exploration that can be provided for the architects in the virtual reality environment during decision making processes not only increase VR benefits and potentials, but also create an effective platform for communication and designing among the design team and stakeholders.

This paper reports a VR function developed by the researcher, which enables visualizing and simulating the analysis of various environmental factors as visual and textual data inside the VR model. The VR function was included in the Microsimulation Plug-in of the commercial VR program, VR Studio Program version 11, by the Program developers. The paper describes the algorithmic details, and how it links the visualized analysis and images to the spaces and zones that the Program user navigates inside the VR model. The paper proceeds to present a VR model as an application to manifest the VR function's advantages in conceptual designing. The concluding remarks accentuate this VR function with its potential uses in microsimulation in different fields such as road designing, urban planning and urban designing.

Environmental Factors Analysis and Computer Programs:

The paper attempts to classify the current computer programs involved with the analysis and simulation of environmental factors, in order to highlight their simulation potentials.

- Energy Modelling Software.
- Day-lighting / Lighting Software.
- Life Cycle Assessment, LCA Tools.
- Rating Systems: For example, LEED.
- Sun Angle Calculators.
- Carbon / Ecological Footprint Calculators.

All the computer programs of Environmental Factors Analysis offer detailed analysis that presents an effective assistance for architects in conceptual design and even in-detail working drawings. Moreover, their analysis simulations provide another level of design assistance. However, all those programs' simulations share a characteristic that is no walkthrough available; in other words the user visualizes the analysis' simulations from an out-of-the-building point of view, or the analysis' graphs, figures and images outside the model itself. The paper focuses on Energy Modelling Software.

Paper rationale and objective:

The analysis of those Energy Modelling programs has various advantages such as the in-detail results and the outputs of different formats -2D and 3D simulations, graphs and tables. However, there are two main disadvantages particularly in the case of collectively considering the analysis of different environmental factors:

- Simulation is either in the program platform itself or as output images of different graphs, tables and textual data. Therefore, a main characteristic shared by those programs is that the simulation cannot be viewed in the other programs, for example an acoustic simulation in the Ecotect program cannot be viewed in the eQuest program or vise versa.
- Simulation is a type of predefined scenario. There is no walkthrough available or interactive change to the simulated model. Therefore, the user can not navigate or explore the simulated model freely or modify the model design to visualize the modification result analysis.

Considering the impact of all environmental factors during the initial phases of architectural design becomes a vital requirement of sustainable design. The architects and the design team are hampered by the lack of one platform to display the impact and analysis of all environmental factors on building performance, and therefore, to communicate between designers, environmental design specialists and stakeholders. The sole simulation of each environmental area or factor does not facilitate decision making processes whereas the design decisions have to be made collectively not only based on all the available environmental analysis but also by all involved specialists and stakeholders.

The presented VR function attempts at introducing a solution to the above hindrance. The paper objective is to employ the VR environment with its powerful potentials as a communication platform to display visualization and simulation of environmental factors' analysis inside the different spaces of the VR model.

Visualization and simulation in virtual reality:

There are different techniques and methods to control objects visualization and simulation in the VR environment, some of which the VR user can not either interact with the simulation or have any control, for example pre-defined scenario. The paper focus is simulations that provide interaction for the user and enable control over the simulation process of the VR model. Moreover, the presented VR function facilitates further control for the user over the execution process by linking the simulation to the different kinds of environmental analysis. The user therefore can visualize different environmental analysis of each space or zone, which the VR camera navigates into and displays. The details of the used method and the VR function are explained in this paper section.

The VR environment used in this paper is the VR Studio program version 11, developed by Forum8, the software developing company. The researcher created the presented function using XML

algorithm. The VR function was included in micro-simulation plug-in of the VR Studio Program version 11, by the Program developers.

Concepts and Attributes of the Micro-simulation
In VR environments, simulation process in general has four types: analytical, microscopic, macroscopic and hybrid [2]. The presented function employs the micro-simulation technique with the use of XML algorithm. The whole simulation process is controlled by the time slider function of the micro-simulation player. The micro-simulation has a record containing a unique identifier for each simulated object, which is according to the paper focus a space or a group of spaces consisting a building. The XML algorithm has a set of associated attributes and parameters that controls each object within the model during simulation, Fig. 1. These attributes and parameters are intended to represent the proposed preferences that are design alternatives in this paper –whereas other tendencies and preferences can be applied based on the discipline used in the simulation such as urban planning, etc.

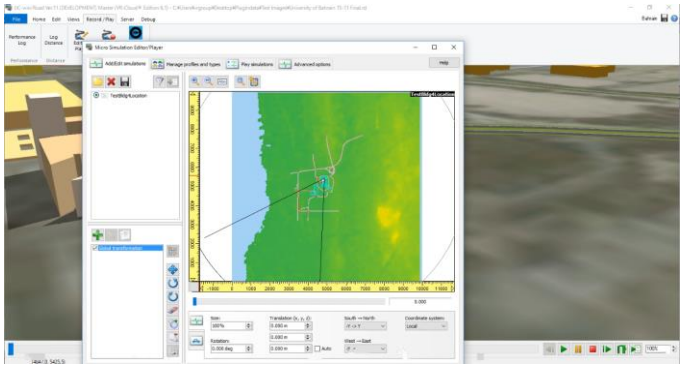

Fig. 1: Executing the XML file in the microsimulation window.

The New Function Details
The main function goal is to simulate and visualize a design alternative concurrently with the environmental factor analysis of its different spaces and zones. The program user can pause the simulation process and navigate inside the VR model at any time during the simulation. The Micro-simulation player executes the XML algorithms through the time slider function. Both the XML algorithm and the time slider control the process of simulation and visualization. Changes can be made easily into the XML code to apply any design change or any alternative [1],[2].

Adding environmental factors analysis in forms of images and textual data to the process of simulation and visualization would not only help architects and the design team communicate and make design decisions effectively but also enrich the VR environment itself.

Working Steps in the VR Program
The following are the working steps in the VR program, Fig. 2.:

- Objects that would be controlled in simulation and visualization are modelled using any computer modeling program -3ds max, AutoCAD, etc-. Those objects should be imported into the VR Design Studio program.
- XML algorithm is created to have the following attributes: simulations, objects and images.
- Simulation has variables that are Units and Frames. More than one Simulation can be created to control different VR model's parts. Units are the components of a building design or an alternative and the environmental analysis data related to the components –be a space or a zone. More than one Frame can be used; therefore, the design can be a building or a group of buildings. Each Frame can control a separate building. The Frame has its own variables: Time and Length.
- Objects have unique identifications in the XML algorithm and the VR Studio program. Each object has an ID, a Type and a Name.

- There are three variables of each object in the XML code: Time, Position and Direction, through which simulated objects can be controlled, be it, the parts of a design alternative or the analysis data of each part.
- Images representing environmental factors analysis and design spaces would be simulated and visualised according to their different times and positions.
- The object position would be linked to VR Studio Program camera with two variables: Position and Area. Hence, the camera as soon as is at any target position -a certain space or zone- the environmental analysis and images related to this position would be visualised in pop up windows.

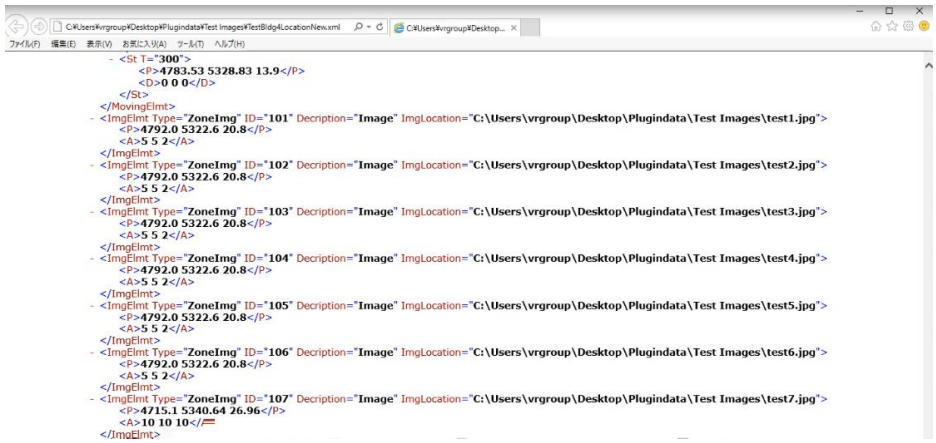

Fig. 2: XML algorithms.

Application of the new function:

A design alternative associated with its spaces' different environmental analysis is used to display the validity and advantages of the VR function. The design is a new building in the University of Bahrain. In this application, the VR Studio program is used as a communication tool and a decision making platform by the design team. The environmental factors analysis was used to make various decisions on the levels of building location and building spaces:

- Building location:

Design team can make a comparison between environmental factors' analysis of different sites in the VR environment, in order to select the most appropriate site. Another benefit is to visualize the analysis related to different areas of the same site. In Fig. 3., the pop-up windows displaying the environmental factors analysis of a specific area in the site, resulted from a certain orientation of the building, appear when the camera is inside the specific area.

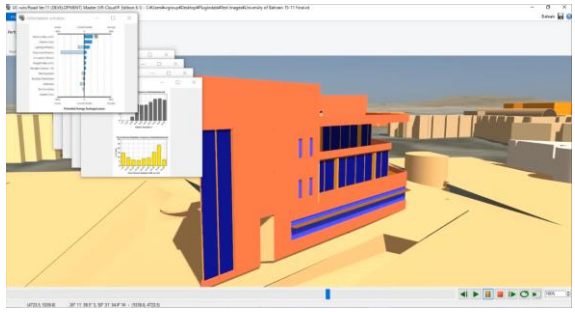

Fig. 3: Building location and its environmental factors' analysis.

Fig. 4 shows the pop-up windows after being arranged. As a result, the decision related to the building's orientation and site would be discussed by the design team based on all different environmental factors' analysis that are displayed in one platform –VR environment.

Fig. 4: All different analysis displayed in one platform

- Building spaces:

The user navigates the entire VR model, whether outdoor or indoor spaces, the analysis relate to each space would appear. Evaluation and decision-making processes are provided more effectively in the light of the analysis of different environmental factors. In Fig. 5., the user visualizes a certain zone, a corridor, while the Program camera displays the environmental factors analysis of this zone.

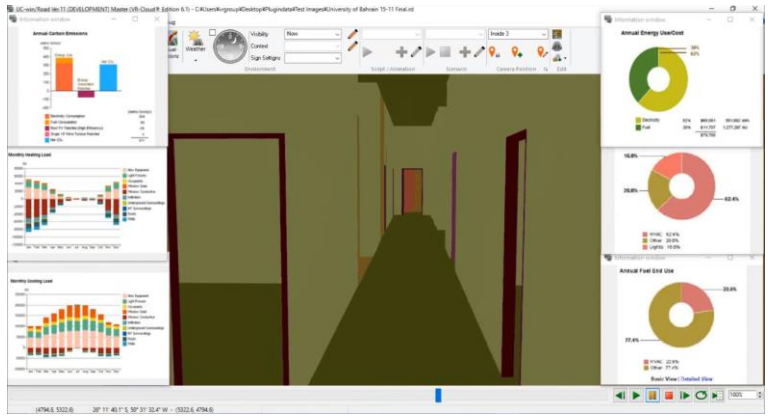

Fig. 5: Environmental factors analysis of building spaces.

Design changes with their environmental factor analysis can be applied in the VR model through the XML file [1], which offer another advantage of the VR function.

Summary and conclusion:

The VR function can be used in areas such as urban designing and urban planning where their schemes of criteria and variables can be visualized and evaluated through the presented simulations. Using environmental factors analysis in the VR simulation and visualization empowers the functions and results with the associated analysis.

Decision makers and stakeholders would have noticeable benefits, represented in achieving real-time interaction in the displayed function through micro-simulation, and in the same time using one platform, VR environment, to display all types of environmental factors analysis related to the building being designed.

In general, the presented simulation's applications have a wide range in engineering, architecture and urban disciplines. However, the function can still be improved in several respects in the future:

- Realistic effects –such as color code- in rendering can be added to the modelling system in the VR environment to highlight certain environmental effects and ranges.
- More function components that can be used in urban designing and urban planning can be added, for example rating system of urban planning have different variables which can be added to the function algorithms.
- Besides the applications discussed in this paper, the VR function can be employed in more various directions. For example, creating series of environmental factors analysis for specific geographic locations annually introduces databases to be used road planning and traffic designing.

Acknowledgements:

The researcher would like to thank Forum8 Company and the software developers for their help in creating the plug in of version 11.

References:

[1] Abdelhameed, W.: Virtual Reality Applications in Project Management Scheduling, Computer-Aided Design and Applications, 9(1), 2012, 71-78. https://doi.org/10.3722/cadaps.2012.71-78

[2] Abdelhameed, W.: Micro-simulation function to display textual data in virtual reality, International journal of architectural computing, 10(2), 2012, 205-218. https://doi.org/10.1260/1478-0771.10.2.205

[3] Bluyssen, P.: Towards new methods and ways to create healthy and comfortable buildings, Building and Environment, 45(4), 2010, 808-818. https://doi.org/10.1016/j.buildenv.2009.08.020

[4] Hopfe, C.; Hensen J.: Uncertainty analysis in building performance simulation for design support, Energy and Buildings, 43(10), 2011, 2798-2805. https://doi.org/10.1016/j.enbuild.2011.06.034

[5] Loonen, R.; Trčka, M.; Cóstola, D.; Hensen, J.: Climate adaptive building shells: State-of-the-art and future challenges, Renewable and Sustainable Energy Reviews, 25, 2013, 483-493. https://doi.org/10.1016/j.rser.2013.04.016

[6] Zuo, J.; Zhao, Z.: Green building research–current status and future agenda: A review. Renewable and Sustainable Energy Reviews. 30, 2014, 271-281. https://doi.org/10.1016/j.rser.2013.10.021.