COLLABORATIVE COOLING LOAD ANALYSIS SOFTWARE FOR PUBLIC PARTICIPATION ON ENERGY CONSERVATION

PUTTHINUN SAWASRATANATHON, PINYO JINUNTUYA
Faculty of Architecture and Planning
Thammasat University, Thailand
c2conun@gmail.com; pinyoji@gmail.com

AND

SONGSAK RONGVIRIYAPANICH
Faculty of Science and Technology
Thammasat University, Thailand
rongviri@cs.tu.ac.th

Abstract: This article is part of a research on developing cooling load analysis software for energy conservation. This research focuses on developing the system of Collaborative Design and Public Participation System which allows property owners, architects, engineers as well as others outside the field, to contribute to design process based on the concept of energy conservation within the collaborative virtual environment. The combination of the two ideas between collaborative virtual environment and Analysis Engine of cooling load calculation changes the traditional working processes in which architects and engineers work separately. From the traditional process where both architects and engineer redevelop the whole project from the beginning when redesigning is in need, this new collaborative process requires less time and energy from both parties due to the simultaneous participation of architects, engineers as well as other contributors.

In this research, Microsoft© Direct3D® - API based Virtools® is used to develop Real-Time Simulation and its internal script in the calculation process. Through the implementation process, the study aims to develop the 3 components of 1) urban area database illustrating simulating maps for users 2) Graphic User Interface (GUI) connected to other software modules for further expansion and 3) Virtual Network Environment allowing multiple users to log in and use the programme at the same period of time.

1. Introduction

Nowadays, computer technology has made the design process for architects easier. Due to its ability to illustrate the work preview before the real construction, architects are able to discuss any issue regarding the design with their customers and thus are likely to create considerably higher customer satisfaction.

In terms of collaborative working process, Internet, as part of the computer technology, makes it possible not only for architects but also customers to make an immediate response and then interact with each other via computers.

Despite its beneficial use, the idea of using the internet technology in the design process is only limited to designing beautiful attractive buildings. There are, in fact, other significant issues apart from beauty which architects should consider.

One of the interesting issues in designing a building is energy conservation. According to the Thai government's statistics in 2006, Thailand's total expenditure in energy accounts for 1,200 million baht. In terms of electricity bills, 70 percent arise from using air conditioners ineffectively. To respond to the problem, Thai government thus creates two campaigns called 'pa-lang-ngan han song' (energy divided by two), and 'hoksib lan jai lod chai pa-lang-ngan' (60 million hearts help to reduce energy consumption) to promote energy conservation in the country. These projects have consequently resulted in the increasing awareness of energy conservation.

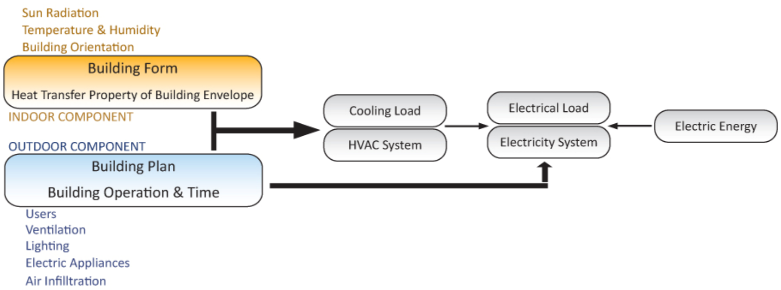

Figure 1. Building's energy consumption.

In correlation with the public awareness of energy conservation, this research aims to develop a collaborative community which possesses a high awareness of energy conservation. As every stage of the design process allows public participation in the virtual environment, individuals can communicate and share their ideas and opinions with few misunderstandings. The development of User Interface System helps users to share ideas and opinions on energy conservation with the ease of mind. This programme is therefore an alternative solution for designing based on the notion of energy conservation.

2. Background

During the preliminary stages of the study, three factors contributed to ineffective design based on energy conservation and are as follows: 1) CAAD software and energy analysis 2) Collaborative design between architects and engineers and 3) the awareness and the emphasis placed on energy conservation. These problematic issues arise from divisional working process which lacks communication described in details below.

2.1. CAAD SOFTWARE AND ENERGY ANALYSIS

Although there are a wide range of Computer Aids Architecture Design (CAAD) tools available such as 'Autodesk AutoCAD' for drawing, 'Autodesk 3DsMax' for modeling, these tools place the emphasis on the design process and design decision support, rather than calculation and analyzing energy consumption. In order to calculate energy consumption, Visual DOE is commonly used. However, it requires time and resources as architects need to type in all the parameters again.

It can be seen that these tools do not support the collaborative design process in which architects and engineers communicate and work together to obtain the most satisfactory result. Architects still work individually and forward their work to engineers so that they can calculate the energy consumption of the building e.g. the size of air conditioners. This process is in fact not economical and does not save energy in the design process.

2.2. COLLABORATIVE DESIGN BETWEEN ARCHITECTS AND ENGINEERS

Different opinions and attitudes among the contributors in the design process is a significant factor. Whereas architects aim to design mainly for greatest satisfaction or beauty, engineers focus more on functionality or durability. Customers, on the other hand, would appreciate when the construction is cost-effective and high-quality. These three perspectives lead to difficulties in the work environment. However, with collaborative participation, all contributors are likely to face with few misunderstandings and are encouraged to work together on the awareness of energy conservation.

In terms of the real-time environment system, it can increase the efficiency of collaborative work. Apart from reducing the number of overlapping, all parties are able to view the same picture which helps them to avoid any possible misunderstandings. For instance, when adjusting the building's attributes in respects of fin and overhang, Overall Thermal Transfer Value (OTTV) would consequently change. In this case, the discussion on concerned issues such as cost, cost-effectiveness, or even beauty can be made through this real-time environment.

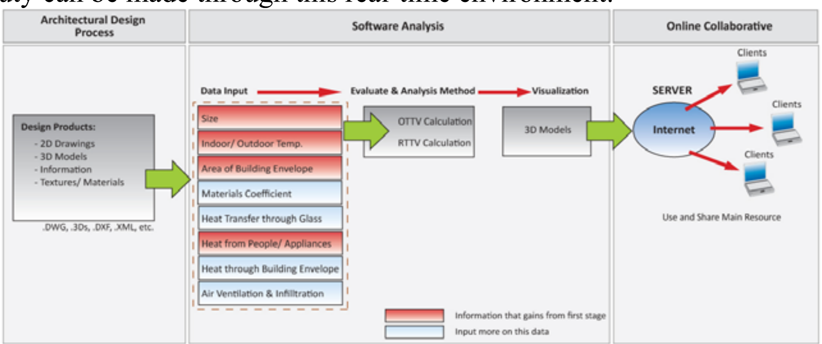

Figure 2. The process of collaborative design.

2.3. THE IMPORTANCE OF ENERGY CONSERVATION AND CONCERNS TOWARDS IT

Thailand's King Bhumiphol has a great interest in researching energy conservation. With his awareness of energy conservation, he began his projects on experimenting substituting energy for future use. A number of governmental projects such as 'pa-lang-ngan han song' (energy divided by two), and 'hoksib lan jai lod chai pa-lang-ngan' (60 million hearts help to reduce energy consumption) also respond to the King's notion on energy conservation. These campaigns include concepts such as turning air conditioners on at 25 degree Celsius, and driving at 90 kilometers per hour to reduce petrol consumption.

3. System Design and Development

In this research, the 3D Application programme needs to developed the following aspects

- Real-time simulation rendering
- The ability to run on the server which allows multiple users
- Supporting construction database management

The above components are used as the criteria of selecting programmes to develop in this study. Open source, freeware programmes as well as commercial 3D game engine are interesting options as they provide what are required in this research. 3D game engine are available in various forms such as FPS (first person shooting), Action, or MMORPG (Massive Multiplayer Online Role Playing Game) (Sallkachat, R. and Choutgrajank, A., 2003). Among these the 3D game engine, MMORPG is the most appropriate for this study as it is a system which allows multiple users to share resources within the virtual community. This virtual environment can be applied for the case of collaborative work in three aspects of

1. Real time simulation rendering. Certain parameters can be adjusted or changed and then synchronized so that all parties can view the same picture. For example, when there are some additional components to fin and overhang or glass material of the construction, all parties will be able to see the possibility of these additional parts.
2. Running on the server which allows more than 2 participants to work at the same time and talk via this server.
3. Supporting database. In some cases where adjustments in design and materials are highly demanded, the programme would be able to support data transfers on the server. The changes and the load cooling calculation would be analyzed afterwards.

In this research, the selected 3D game engine is Microsoft © Direct3D®-API based Virtools® (Yeo, W., Lou, C., Kaga, A., Sasada, T., Byun, C. and Ikegami, T., 2003). The processes include real-time simulation, server connection, database management and user interface building through programme scripts.

3.1. INTEGRATING REAL-TIME ENGINE COOLING LOAD ANALYSIS TO CAAD ENGINE

At the preliminary stage, the internet connection is not required as this phase focuses on energy calculation in which static values and variables are used.
Developing a component of energy calculation is a main part among those which calculate and analyze the energy consumption of the construction. These calculation formulas include “Overall Thermal Transfer Value Calculation” (OTTV) and “Roof Thermal Transfer Value Calculation” (RTTV) (American Society of Heating, refrigerating and Air-Conditioning Engineers, Inc., 2001).

$$OTTV = U_w(1\text{-}WWR)(TD_{eq}) + (SC)(WWR)(TD_{eq}) + U_f(WWR)(\Delta T) \quad (1)$$

$$RTTV = U_r(1\text{-}SSR)(TD_{eq}) + (SC)(SSR)(TD_{eq}) + U_f(SSR)(\Delta T) \quad (2)$$

When:

OTTV	=	Overall Thermal Transfer Value (W/m^2)
RTTV	=	Roof Thermal Transfer Value (W/m^2)
U_w	=	Total Coefficient Thermal Transfer for Solid Wall (W/m^2.^{o}C)
U_r	=	Total Coefficient Thermal Transfer for Solid Roof (W/m^2.^{o}C)
WWR	=	Ratio of Window Area and/or Translucent Wall to that Side Wall Area
SSR	=	Ratio of Natural Open Void to All Roof Area
TD_{eq}	=	Comparison Differentiate between Indoor and Outdoor Air Temperature
SC	=	Shading Coefficient of Window
U_f	=	Coefficient Thermal Transfer of Window or Translucent Wall (W/m^2.^{o}C)
ΔT	=	Differentiate between Indoor and Outdoor Air Temperature (For Thailand is 5^{o}C)

This part is developed by setting static values and variables on internal Virtools® script language to integrate with construction database in the next phase. For real-time environment, a script and a frame is created to display the value of energy consumption of building which will change according to the attributes of the building.

3.2. COLLABORATIVE DESIGN FOR ARCHITECTS AND ENGINEERS

Collaborative design system development process is mainly about term of support architects and engineers to communicate each other for energy conservation process. This part is about creating tools that help users to manage in architectural construction. This phase is concerning on application and operation that mostly used in actual construction as main idea for using as menus in this research.

3.3. NEW GUI SYSTEM FOR ENERGY CONSERVATION DESIGN

In the stage of developing user interface system, the main concept in the development is that it should be easy to understand and appropriate for computer users with versatile skills. Restrictions on connection and information access are also emphasized. The development, thus, includes a user log-in system where users have to type in their user names and passwords before using the programme. Moreover, tools such as chatting tools and camera adjustment tools are also developed in this stage.

Chat windows and chatting tools which are developed from the concept of virtual community are placed on the bottom left of the analysis screen. This part is used to control the communication or chats among collaborative users on virtual space using the programme Virtools® Multiuser Pack.

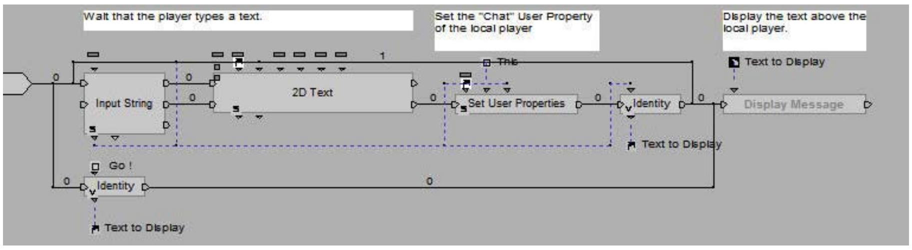

Figure 3. Diagram shown chatting method.

At the bottom left next to the chat windows are tools for adjusting the attributes of the building and tools for controlling the camera. To accommodate users a user-friendly programme, all controlling buttons are in form of icons accompanied by short information text.

On the top right, there is the window displaying online users and active users, and the other window displaying the value of energy consumption analysis. Through these windows, users are able to view online users and see the changes in value of energy consumption which occur according to the changes in the construction attributes. The displays at this stage are in the real-time process.

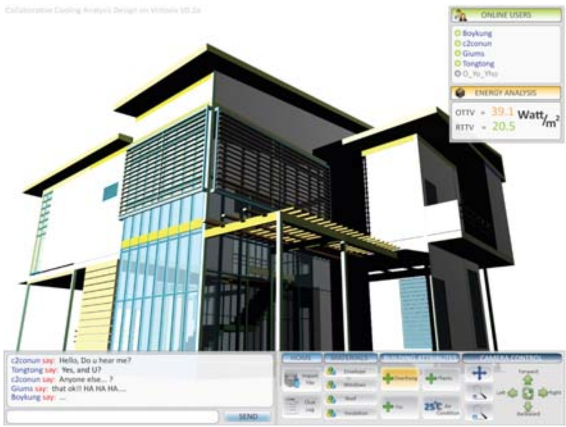

Figure 4. New Graphic User Interface Applied from 'Online Game'.

3.4. DATABASE MANAGEMENT SYSTEM FOR CONSTRUCTION MATERIALS

Construction material database refers to the database of solid wall, translucent wall and glass materials which are commonly used in actual construction. In this stage, it deals with database management system for construction materials such as increasing the number of fin and overhang or the number of trees surrounding the building, and setting the air conditioner volume at 25 degree Celsius. The database here is linked to the previous energy consumption phase through script writing using the programmes Virtools® Dev and Virtools® Multiuser Pack to enable real-time display. Users can adjust the static values set by the programme and then compare the changes in energy consumption.

3.5. MULTIPLAYER ONLINE VIRTUAL ENVIRONMENT TO ENCOURAGE ENERGY CONSERVATION CONSCIOUSNESS

This stage of the study involves developing the network server system of the programme by using Virtools® Multiuser Pack in creating a server of virtual space environment. To test the programme application, 4 sample users participate in closed beta format and then connect to the network server. To test the collaborative participation, the four users adjust the design of fin and overhang as well as adjust the temperature setting to 25 degree Celsius. As a result, the participants see the possible changes they can make in the design. Chatting within the virtual environment is also included in the test to check whether all participants are able to communicate via the programme.

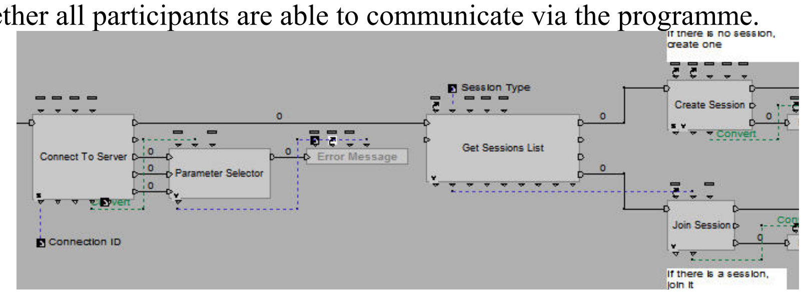

Figure 5. Diagram shown server connecting method.

4. Software Implementation

To test the software, the software is run on the server in the laboratory of the Faculty of Architecture. Both university students and lecturers pay a great intention to this software. The user interface system developed from the idea of virtual community on the internet attracts university students for software trial. This situation shows that there is a high possibility of this software becoming popular, especially among those who are interested in the work of energy conservation. If the programme becomes widely accepted and its users understand its principles and theories, it can lead to collaborative energy conservation at the national level.

Using the software at a national level helps to create understanding on energy conservation within the nation and energy conservation would then become much more effective due to people's awareness of the issue.

Furthermore, a wide use of this software contributes to the development of construction material database, which can be used as the main reference where people can log in and make some changes for improvement.

5. Conclusion & Future Development

The objectives of the research are to create a new format of public participation as well as to raise an awareness of energy conservation amongst the public. According to the Construction Act of Thailand, Energy value calculation of OTTV and RTTV is the compulsory process prior the construction. The research understands its significance and therefore includes this process in the first part of the research.

Adjusting physical components such as adding or removing the shading of building and building operation attributes are the main features that are implemented. The virtual environment for public participation by connecting via the Internet is created for this prototype software. This software is aimed to be a guideline for those who are interested in energy conservation in hope that they can share their knowledge and opinions with others.

This software is expected to be able to change the construction materials such as solid wall, translucent wall and glass. In addition, it is required to have an imported 3Dmodel function so that customers can use this 3Dmodel for consultation with the engineers or architects

Acknowledgements

We would like to give our thanks to Mr. Chakrapan Pawangkarat who has given invaluable advice on cooling load analysis method and construction materials database in this research.

References

Al-Sallal, Khaled A.: 2003, Integrating Energy Design into CAAD Tools, *CAADRIA03*, Thailand, PP323-337.

American Society of Heating, refrigerating and Air-Conditioning Engineers, Inc.: 2001, *2001 ASHRAE Handbook: Fundamentals*, Atlanta, Georgia, pp. 28.1 – 29.38

McQuiston, Faye C., Parker, Jerald D. and Spitler, Jeffrey D.: 2000, *Heating, Ventilating, and Air Conditioning Analysis and Design (Fifth Edition)*, John Wiley & Sons, Inc., New York, pp. 215-273

Mourshed, M. M., Kelliher, D. and Keane, M.: 2003, *Integrating building energy simulation in the design process,* IBPSA News, Vol. 13, No. 1, pp. 21-26.

Oughton, D.R. and Hodkinson, S.: 2002, *Faber and Kell's Heating & Air-Conditioned of Buildings (Ninth Edition),* Buttonworth-Heinemann, Oxford, pp. 124-156

Sallkachat, R. and Choutgrajank, A.: 2003, Collaborative Design: Integrating Game Engine to Online Interactive Presentation Tool, *CAADRIA03*, Thailand, PP295-306.

Yeo, W., Lou, C., Kaga, A., Sasada, T., Byun, C. and Ikegami, T.: 2003, An Interactive Digital Archive for Japanese Historical Architeture, *CAADRIA03*, Thailand, PP513-522.

Yu-Shen Ng: 1997, Internet Game Design, Gamasutra, August 1, 1997, http://www.gamasutra.com/features/19970801/ng.htm.