

CONFERENCE
PROCEEDINGS

**3RD INTERNATIONAL
ACADEMIC CONFERENCE ON
PLACES AND TECHNOLOGIES**

EDITORS
EVA VANIŠTA LAZAREVIĆ
MILENA VUKMIROVIĆ
ALEKSANDRA KRSTIĆ-FURUNDŽIĆ
AND ALEKSANDRA ĐUKIĆ

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PLACES AND TECHNOLOGIES 2016

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Eva VaništaLazarević, Milena Vukmirović, Aleksandra Krstić-Furundžić, Aleksandra Đukić

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PLACES AND TECHNOLOGIES 2016

KEEPING UP WITH TECHNOLOGIES TO CREATE COGNITIVE CITY
BY HIGHLIGHTING ITS SAFETY, SUSTAINABILITY, EFFICIENCY,
IMAGEABILITY AND LIVEABILITY

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DIGITAL TOOLS-BASED PERFORMANCE EVALUATION OF THE ADAPTIVE BUILDING ENVELOPE IN THE EARLY PHASE OF DESIGN

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ABSTRACT

Amelioration of indoor comfort for the building occupants, reduction in energy consumption and carbon dioxide emissions can be achieved with application of an adaptive building envelope in new and old buildings.

Nowadays, there is a lack of methods for predicting and evaluating the performance of the adaptive building envelope at component and whole building scale. Also there is a need for guidance on how to model the adaptive envelope system and how to simulate one in a suitable way.

The aim of the paper is to review the existing literature and projects on methods, techniques and strategies for the adaptive envelope performance assessment in the early phase of the design (in scope Computer-Aided Architectural Design - CAAD).

Authors are currently carrying out a classification, critical and comparative analysis of the existing simulation and modelling approaches for the adaptive façade with focus on the design of exterior shading systems. After the aforementioned analysis they have implemented workflow proposed on a case study.

The case study is discussed to show how the method proposed and based on digital tools can be applied. Numerical simulation is conducted to predict and to evaluate performance and possible energy reduction application of the adaptive exterior shading system. In this case geometry and material characteristics of shading systems are investigated in relation to daylight and light performance of indoor space.

Keywords: adaptive envelope, digital tools, early phase of design, performance assessment, shading systems.

INTRODUCTION

Climate changes and growing sensitivity toward energy consumption have inspired designers with new challenges regarding the design of the environment. In the construction industry the

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energy consumption is the highest and innovative solutions, new and different design approaches need to conserve energy. The building envelope is one of the most important parts of building that contributes to energy efficiency of building and thus low environmental impact. Design of the building envelope influences on the consumption of energy and indoor comfort quality. In this sense, adaptive envelopes can provide extreme benefits.

The building envelope performance directly influences cooling and lighting energy consumption. According to ASHRAE Fundamentals Handbook (2009) one of the most important ways to reduce overheating of interior spaces and reduce energy required for cooling is to block direct solar radiation before it reaches the glass. Olgay states that "the most sensitive single element of the structure is the window area. Its positioning for winter and solar control during summer produces the largest effect on heat flow balance" (Olgay, 1963). Also quality of the fenestration, frame and glass, may influence the reduction of solar heat gains. When designing adaptive building envelopes, one of the main challenges is designing the outer layer of the envelope – shades, which in extreme cases should prevent overheating the interior space, and at the same time enable sufficient penetration of daylight inside the object.

Modern scientific and technical achievements offered new possibilities for designing shading devices. The role of the adaptive envelope is to control energy flows between the interior and exterior of the building, and thus with adaptive envelope it is possible to manage the energy consumption for cooling, heating, lighting and ventilation of indoor space. For the façade, design is believed to be crucial in achieving zero energy buildings or an overall reduction in energy consumption. Also, it is necessary that the architectural, structural and building physics requirements are integrated in the design of the adaptive facade system. Shades can be designed as movable objects that move according to the Sun. Other possibility is designing shades that are immovable and whose shape and position are optimized based on the geometry of the Sun on the annual level. Both approaches offer new dynamism of forms and shapes.

The study offers some important insights on relation between the performance evaluation, the early phase of design, and the adaptive building envelope. But the paper does not engage with practical constraints. The overall structure of the paper takes the form of three sections. The first one begins by laying out the importance of the early phase of design. The second section considers the adaptive building envelope and the third section discusses the performance evaluation based on digital tools including presentation of the case studies. Throughout this paper, the term digital tools will refer to small or big programs, plug-ins, add-ons or scripts which are based on computational logic and on algorithmic procedures.

THE EARLY PHASE OF DESIGN

It is often practice in designing process to consider the building physics and check the energy performance of project when the designing process is nearly the end and project solution is already defined. In many cases, completed project does not fulfill the requirements of building physics and then it is necessary to create many modifications or corrections of the project or in many cases start all over again. The alternative is to consider the building physics and to assess the energy performance from the very beginning of the designing process and so searching for successful solution. But mostly, tools and calculating methodologies are designed to be used on developed solutions. Working procedures, in relation to early designing stage and using of digital tools, are undefined and in phase of developing. Petersen Steffen et al. (2010) in the article *Method and simulation program informed decisions in the early stages of building design* state that today is needed to develop practical design technique to reach high energy performance building, especially in early phase of design, because advice design tools are not well developed and limited to evaluate energy performance of building by designer. Some reasons are: the need to find, develop, check and then compare the many possible solutions in a short time period, but to do so requires accurate and valid information so that architects can make the right decisions.

Lack of working procedure for designing dynamic shading system, especially when choosing and using digital tools is noted.

THE ADAPTIVE BUILDING ENVELOPE

During the past half century a number of research papers, books and projects have been published suggesting different ideas about the building ability to adopt changeable circumstances. In the book *Soft Architecture Machines*, Negroponte Nicolaus (1975) states that buildings need to adapt to environmental conditions and human demands and needs. Some authors have mainly been interested in the adaptive architecture concerning the interactivity regarding to environment's and users' changes, like John Frazer (Frazer, 1995), Mike Weinstock (Hensel et al., 2013), Cedric Price (Mathews, 2006) and Gordon Pask (Pickering, 2010). Michaela Turrin et al. (2011) in *Parametric modeling and optimization for adaptive architecture* have noted: "... adaptive architecture is based on the interdependence between the varying needs/demands and the capacity of a building to satisfy them in a changing environment". Jan Knippers and Speck Thomas (2012) in the article "*Design and construction principles in nature and architecture*" use the term *convertible structure* to define an adaptive building envelope that is able to change its geometry. This paper presents the adaptive behavior as process in which the building envelope transforms from one form to another one and has ability to self-adjust to changeable user's needs and demands and to changeable situations in environment.

Designing the shading systems

To date, several studies have examined the association between workflow approaches and the design of louvers. In the book *Sun, Wind & Light: Architectural Design Strategies*, Mark DeKay et al. (2014) provide us with the strategies for design external shading devices. Olgay Victor (1963) presents approach to analytical design of shading systems in the book *Design with climate: bioclimatic approach to architectural regionalism*. Mazria Edward in book *The Passive Solar Energy Book* (1979) further developed aforementioned Olgay's graphic method for shading systems design. From then until now, the approach of Mazria and Olgay to design and devise louvers has been improved and advanced.

In Methods and approaches in designing shading systems were the same for a long period but in the past two decades the breakthrough has been made in this area. In this period many authors developed different methods based on computation technologies. Among the many methods for designing louvers, a method called Eco thermal method, Eco Degree Day method or Shaderade method should be noted. Sargent et al. (2011) presented the use of this method in designing shading system and noted that it enabled achievement of the best results and the greatest energy savings. This method is incorporated in DIVA, and used in case study analysis.

THE PERFORMANCE EVALUATION

The designers/architects need the knowledge about techniques and strategies for the use of digital tools to assess specific performances of adaptive envelope in the early phase of design. In this case the strategies means a set of decisions regarding the way in which architects/designers can perform the process of designing adaptive building envelopes on the basis of digital tools. This particularly applies to the collection of relevant information and processing and inclusion of this information in the conceptual design in accordance with the requirements of the design. Proposed design workflow is divided in a several steps: defining working criteria; making parametrical models; simulation and analyzing; measuring and assessing performance; preparing data for manufacturing and fabrication; also process optimization can be considered; physical simulation and testing prototypes.

Digital-tools

In the past several years, many digital tools were developed and many researches were conducted. In this paper, the digital tools that architects use to design, check and test the exterior shading system of the building envelope are presented. End-user development (EUD) is based on visual programming tools such as RhinoScript for Rhino, MEL for Maya, DesignScript for Revit etc. With these tools the end user automates and customizes sub tasks during design process. A visual interface of this tools help architects/designers to end-user development (EUD) without high level programming knowledge. The main aim of this script is to give opportunities for repetition and automation during design process. Tools include knowledge of building physics which is the basis for designing that should contribute to preservation of the environment and user's wellbeing. Grasshopper (visual programming plug-in for RhinoCeroes) within RhinoCeros platform is used in design process to parametrically make geometry of shading system, envelope and building. These tools aid the architect/designer to use the least necessary geometry to cover the opening on the building envelope during a certain period of the day. In other words, using these tools designers can determine the geometry of the shades in relation to geometry of the movement of the Sun for a specific location.

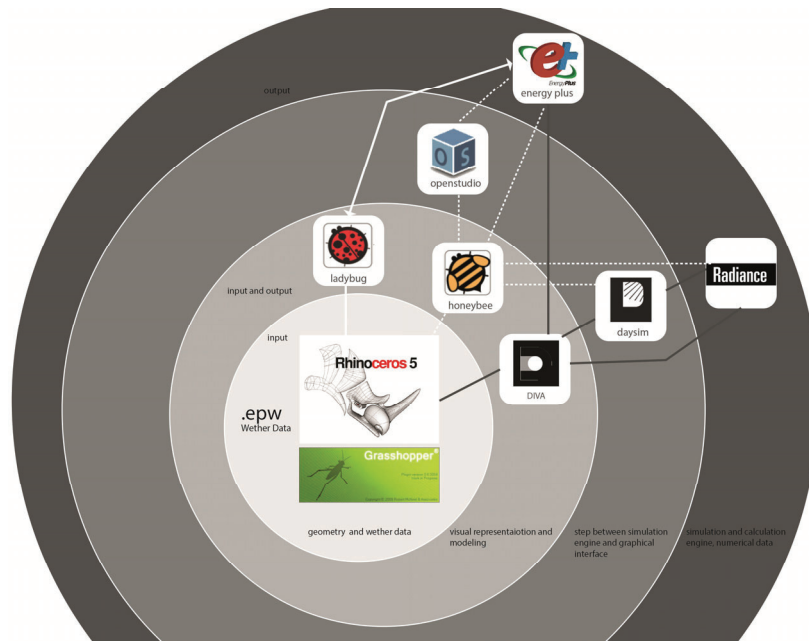


Figure 1: Diagram of relation between digital tools within Rhinoceros platform that are used in design process of an adaptive envelope.

In the past few years, digital tools for Rhinoceros platform have been developed to simulate energy flows in an architectural design at different levels – from component level to urban contexts. This tools (Honybee, Ladybug, DIVA, geco, Archisim) link the working environment Rhino with EnergyPlus when calculating thermal properties, and Daysim, as part of Radiance, when calculating daylight in interior spaces analysis (Figure 2). For example, the tool DIVA is used for performance design. Using this tool it is possible to check the lighting and thermal properties of the model, within Rhinoceros platform.

The case study office building in New Belgrade, Serbia

The following section will discuss in detail above mentioned workflow for the early phase of design (Figure 2). Here is presented basic information about the design of the exterior shading system for the office building located in New Belgrade, Serbia. Here is offered the method for assessing daylight performance in the effort to reduce energy consumption and to achieve visual comfort. Firstly, weather data for Belgrade city are considered. Then a typical office story has been selected to be the model for testing. The parametrically made model of the office unit and the shading systems is created. Subsequently is made input for simulation to test design solutions of shading systems.

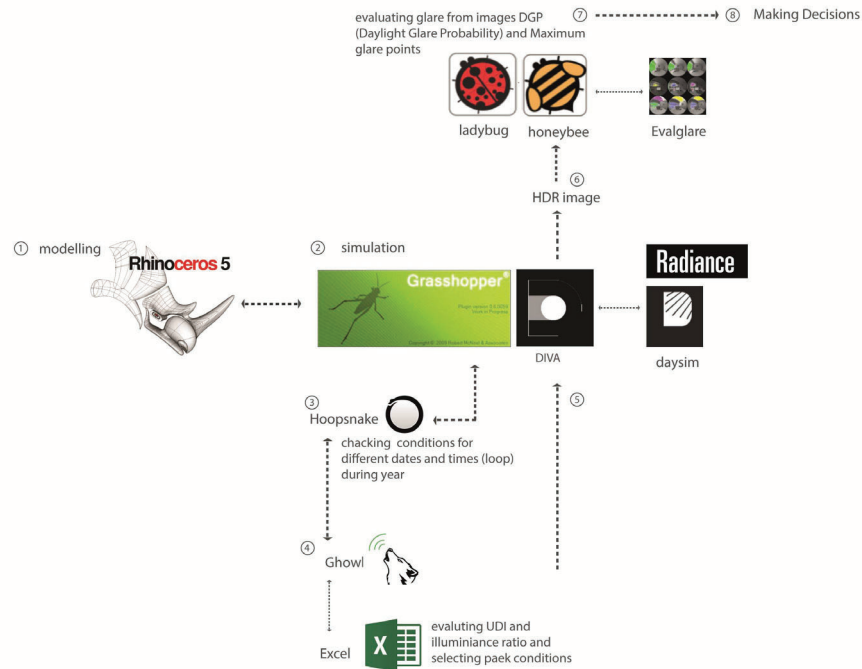


Figure 2: Diagram workflow of the performance evaluation for the visual comfort (1 Input parameters, 2 calculation/simulation, 3 assessment and evaluation, 4 making decisions, 5 implementation/redesigning).

The office building is located in New Belgrade at latitude $44^{\circ} 48'N$ and longitude $20^{\circ} 27'E$. The orientation of the typical office unit is the south. The building has the facade without the exterior shading system; the glass transparency and the interior blinds are used to control thermal and daylight performance in the building. This case study based on the parametric geometry, is used to investigate the geometrical characteristics of exterior shading systems and their influence on thermal and cooling loads, and on the daylight performance in the interior office space.

The Figure 3 shows parametric modeling that was used to define geometry of typical story and exterior shades. Several steps were conducted: division of office building on stories and choosing of a typical one. At the beginning, the selected story was separated from the entire building, and then measuring and testing were performed using simulations. Dimensions, such as story height, front width, and walls, openings and floors ratio, were parametrically entered so that they could be changed by changing the values of these parameters. Then the defined geometry was divided into components, for example: floor, ceiling, walls, roof, doors and windows, so that the specified geometry could be recognized as a totality in digital tools EnergyPlus and Radiance.

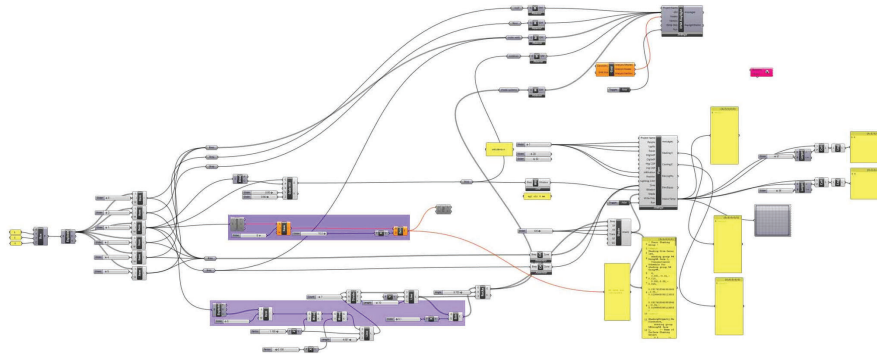


Figure 3: Parametrically defined model: geometry of typical office unit with exterior shades (EUD-Grasshopper)

Simulation and verification of daylight performance is done using the next metrics: annual heating, annual cooling, artificial lighting, DA_{500lux} and $UDI_{00-0000lux}$. Standards for daylighting were considered according to *IESNA Lighting Handbook* (Quality of the Visual Environment) and the used value of minimum luminance for working space in office building was 500lx. This value is expressed as a percentage and represents the time during the year when workspace is being used and minimum illuminance requirements are met, using only day/natural light. At beginning of the simulation process, the input values are entered for the location in Belgrade. Then, a characteristic material was added to each layer which contains geometry. This is necessary in order for Radiance to be able to identify which components have which reflection, absorption or transparency, so that the simulation of lights arrangement could be performed. Then positions of nodes - sensors were defined, setting the plane and points, on which the illuminance was measured.

CONCLUSIONS

This paper is presenting traditional and contemporary methods of designing shading systems. This paper explains the workflow that could help designers/engineers to make effective and informed decisions in the early phase of the shading system design. This is presented as a simplified method for a predicting visual and thermal performance of interior space considering a design of a shading system for office building in the early phase of design. Shading system is defined parametrically and then optimized to reduce energy for lighting and to achieve visual comfort of users. We believe our work could be a starting point for future investigation. One area of future work will be to represent: relationships between models and tools explicitly, in the detailed phase of design. This work should benefit greatly by using data on Building Information Modelling (BIM) and Building Energy Modelling (BEM).

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