Parametric Design Based on Building Information Modeling for Sustainable Buildings

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***Abstract*— The kinetic expression of building has been the sublime pursuit of contemporary architectural design in recent years, but the kinetic components of building also may further the building energy efficiency. This article suggested kinetic envelopes responding to extreme climate conditions with a great range of changes may offer a promising building energy saving. This research reviewed important literatures involving kinetic/interactive building projects and Building Information Modeling (BIM). Then, the study placed it into a design case as the implementation by using programming and Autodesk Revit's Application Programming Interface (API). In conclusion, this article developed a prototypical tool, for the design case, which offers an effective access to connect computational building modeling and climatic parameters, and in turn facilitates the new approach to sustainable buildings.**

Keywords- parametric design, building energy, building information modelling, sustainable building

I. INTRODUCTION

Building energy efficiency is the pursuit of architectural design. In particular, there are many locations with extreme climatic conditions like the great daily or seasonal variation in climatic temperature. The temperature of Beijing, for example, can swing around 40 C° degrees from winter to summer and around 10 C° degrees from night to day [1]. Currently, the common strategies for addressing this wide temperature range of climate are the HVAC (Heating, Ventilating and Air-conditioning) systems. Thus, much energy of HVAC system is consumed in these locations for keeping the indoor thermal conditions within certain temperature zones.

Although lots of studies have been related to the high-tech or high-efficient HVAC system to save energy, we believe the fundamental point is the architectural design rather than external treatment like the HAVC system. That is why many design standards and handbooks are used for recommending building orientation, materials and other design strategies for reducing the energy usages of HVAC systems. The solution to this specific climate is about developing the kinetic envelopes which have the interactive and responsive access to natural energy like solar radiation, seasonal wind and etc.

Ideally, the resulting kinetic building envelopes will intelligently provide natural energy and reduce energy usage of HVAC system according to outdoor climate condition, which creates an "Acclimated Building". The development of Building Information Modeling (BIM) revolutionized the building sustainability and other domain knowledge. Especially, this BIM-based parametric design method incorporating Application Programming Interface (API) of BIM authoring Autodesk Revit is used by this research.

II. THE STATE OF ART

A. Kinetic Building and Envelopes

The issue of kinetic architecture initially was first demonstrated by the literature "Kinetic Architecture" wrote by William Zuk and Roger H. Clark in 1970. It shows the systematic knowledge about kinetic architecture, also proposed the combination between natural models and buildings [2]. His research doesn't only propose the kinetic building conception, but also interprets different possibility related to kinetic building components including building envelopes.

Current intelligent kinetic systems arise from the isomorphic convergence of three key elements: mechanical engineering, embedded computation and responsive architecture. Thanks to the development of emerging high-tech building systems from Europe, building envelopes are tend to more smarts and moving parts[3]. Aesthetics and technology are converging in many places related to kinetic building envelopes. Nonetheless, the most drivers for kinetic building envelopes are for exploring sublime geometric representation and optimization rather than sustainability.

Actually, building envelopes' properties including lighting and thermal conditions are very important design elements affecting final building energy performance [4]. There are a some of practices and research consistently justify that interactive envelopes can offer promising energy savings and indoor comfort [5, 6,7]. For instance, the responses of lighting capture of cameras' shutters inspired an interesting façade of Arab World Institute designed by Jean Nouvel in Paris (Fig.1 left). The kinetic envelopes will control the amount of incident sunlight according to the outside daylight illumination conditions. In the result, the indoor lighting environment will be balanced and save the electrical lighting energy. Another telling example involves automated shades which have the attributes of highly transparent and relatively unarticulated building enclosures. In addition, the envelope systems of the Gemeinnützige Siedlungsund Wohnungsbaugesellschaft (GSW) headquarters building (Fig.1 right), designed by Sauerbruch &

978-0-7695-3972-0/10 $26.00 © 2010 IEEE
DOI 10.1109/CESCE.2010.285

Hutton Architects, demonstrate the views that the envelopes of buildings may like the skins of living organisms to breathe, change form, and adapt to variations in climate [6]. Its kinetic envelop systems offer the naturally ventilation for 70 percent of the year, and provide extremely good daylight to the office floors through shading systems and much reduce the need for electrical lighting [6].

Figure 1. Arab World Institute and GSW headquarters building

These studies and literatures of kinetic building envelope issues present our research with the practical and sustainable insight into how to explore and manage the envelope behaviors.

B. *Building Information Modeling (BIM)*

The design process in architecture consists of an iterative cycle that moves from a design according to specific criteria like thermal comfort to a new phase of design development. This design process has been substantially transformed in recent years by the introduction of Building Information Modeling (BIM). The 3D knowledge-rich parameters are the fundamental point for BIM conception which authors several modeling platforms like Autodesk Revit, ArchiCAD and etc. The building model established on these platforms will have multi-parameters including constructions, materials, costs and user defined parameters. Those parameters provide a possibility of connecting geometric information to the real world architectural requirements like sustainability.

Also, specific knowledge in BIM have been studied in some research related to the specific parameters of building model and its geometric constraints [8,9,10] to improve the representing and optimizing geometric issues. Furthermore, there are several studies focusing on capturing and describing real architectural needs related to environment sustainability or occupants preferences. For example, Ghang Lee and Rafael Sacks extend BIM modeling to the field of enabling an object in BIM to respond to internal or external stimuli (i.e., change its form in response to changes in its context) through complex constrains defined by users or datum [11]. Another study is from Arno Schlueter & Frank Thesseling who developed a prototypical tool named DPV that facilitates Autodesk Revit to the capability of representing instantaneous energy performance and the visual representation of the outputs[12].

III. IMPLEMENTATION FOR BUILDING ENERGY EFFICIENCY

The kinetic envelopes will also consume the energy to behavior for responding to the changes of surrounding climatic conditions. So, the kinetic modes of envelopes are the centrals of final whole building energy performance. How to find the suitable and efficient solution of kinetic modes?

At the natural biological level, bio-thermoregulation keeps organisms' temperature within boundaries through changing tissue or utilizing natural energy like solar radiation [13]. Scientists have discovered some natural models with high efficient thermoregulation and translated them, like the polar bear's fur and certain mammal's hair, into manageable materials or design [14,15,16]. We believe the biomimetic methods may be possible to explore an effective access to kinetic envelopes.

A. *The Inspiration of Natural Model*

In this section, we used the BIM-based parametric design to form an innovative kinetic building envelope into an architectural project in Beijing, China. We were inspired by the butterfly wings' honeycombed microstructure. Discoveries on butterfly wings show that the honeycombed microstructures on the wings' surface can be the effective solar collectors [17] or blocks [18]. The honeycombed pattern takes advantage of trapping solar radiation because of the almost total internal reflection; that is, the solar radiation enters the concave combs, and then is partially absorbed and partially reflected but nearly

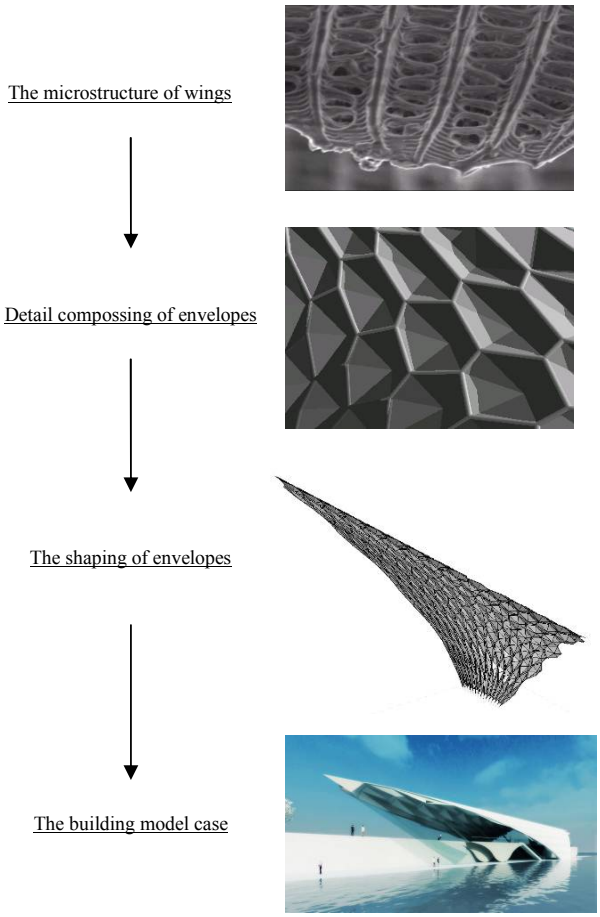

Figure 2. The translating process of bioinspiration from butterfly wings

all the incident radiation was moved within the honeycomb rather than was taken away to outside [19].Conversely, the fold wings minimize the area of surface and avoid many thermal transmissions.

On the basis of these studies, we translated this structure into kinetic building envelope panels with hexagon structures. Each hexagon structure of kinetic building envelope system has a height which will consistently change according to seasonal solar radiation and air temperature difference between interior and exterior. Logically, the kinetic building envelope panels can change to three periodic patterns related to concave, convex and flat [20], among which the concave makes envelopes concentrate more solar radiation to indoor environment, the convex makes envelopes easier heat loss from inside to outside (for example, at the summer night or rainy day), and the flat makes the building envelope minimize the area and retards the heat transfer.

B. The Process of Implementation by Using API

BIM authoring software, Autodesk Revit Architecture 2010, offers an Application Programming Interface (API) designed to allow power users and external application developers to integrate their applications with Autodesk Revit. Based on API, we created a new add-ins to automate repetitive tasks in the Autodesk Revit user interface incorporating the existing plug-in named Solar Analysis Technology.

- Firstly, the Solar Analysis plug-in presents the model with the different levels' solar radiation on the building envelope. Through this method, we can differentiate the each panel parameters of the building envelope into three levels: High, Middle and Low.
- Secondly, the Autodesk Revit building's model needs the update for linking the instance parameters and the project parameters which related to the high, middle and low solar radiation. The reason why we did this work is that the Autodesk Revit API can not directly find the each instance parameters of any deep-rooted families in the project.
- Lastly, by using C# programming, each panel parameter of height can be filtered and set a new value. The principle formula in the API involves the parameters of the height of panels, solar radiations, seasons, indoor and outdoor air temperature. Also, the programming provides the user interface for Autodesk Revit. Note the filter command is from Autodesk Revit API 2010.

This prototypical tool based on Autodesk Revit API enables to form the appropriate kinetic building envelopes involving the constructions and geometry according to the temperature differences between interior and exterior. Also, the occupancy activity is considered during the computational modeling because the activity ways may affect the tendency of indoor building temperature changes and thermal comforts.

Nevertheless, the final energy performance related to cooling and heating is still pending until the resulting building gets the computational simulation through connecting BIM platform to certain energy simulation platform like EnergyPlus, DOE2 and etc. With the further research on simulation, the whole envelope mechanism may achieve a facile and economic

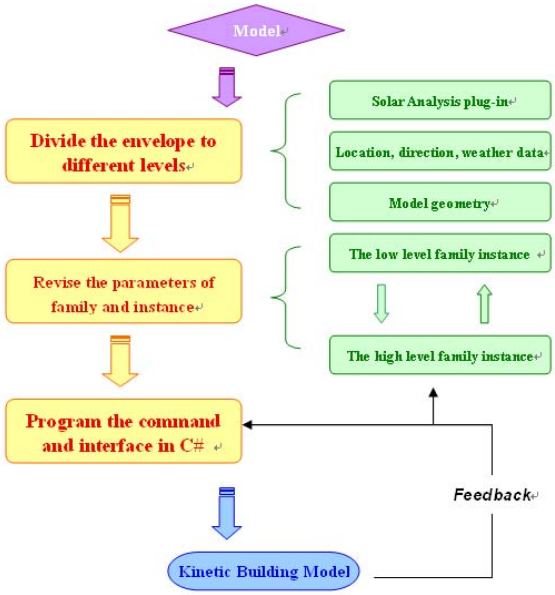

Figure 3. The process of architecture for our case implementation.

design with hierarchically periodic configurations for building energy efficiency.

IV. CONCLUSIONS AND FUTURE WORKS

Through our works, we found the BIM-based parametric design method can effectively make the building modeling and its configuration connected to the real world climatic parameters, and facilitates the study of building sustainability related to energy efficiency.

The BIM-based design also offers an important way to explore the kinetic building components during the process of architectural design. This parametric design conception is different with the common parametric design for esthetic shaping or geometry exploration, but rather can be an effective bridge to connect climate, building energy and indoor thermal comfort. Also, the Autodesk Revit API combining with C# programming is useful to define the kinetic modes and regulations, and the user interface of new plug-in as well.

We wish to further understand knowledge of API functions with Autodesk Revit and establish more complicated relations between BIM platform and Energy Simulation platform. The next step for our research is related to the import methods of real weather data and then involved the simultaneous representation of building components behaviors. We can get the resulting building model information at many points through this representation and modeling process, and in turn analyze the energy performance of the final resulting building envelope system.

ACKNOWLEDGMENT

We wish to Prof. Dr. Wei Yan of Texas A&M University for his inspiration and detailed instructions in BIM, and acknowledge Mark Meagher and Prof. Dr. Jeffrey Huang of EPFL for sharing their helpful comments and bibliography.

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