

A Study of Kinetic Façade Modelling Performance Using Virtual Reality

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Abstract –

Kinetic facades are dynamic building surfaces that manage light, ventilation, energy, or information. The programming of Kinetic facades require a vast technical expertise of building systems, materials and computer devices and constant alteration of models to examine till the desire purpose of the kinetic façade is achieved. There heavy dependence alterations to physical scale models to understand the systems performance. This paper focuses on a building a mechanical building skin that adjust to the sun path to harness solar energy while shading the building and considering unpredictable weather changes which is an inspiration from biomimicry architecture concepts derived from how leaves react to sunlight in nature rather the conventional fixed photovoltaic panels. Using rhino grasshopper plugin we design and find geometric forms representing panels that can optimally harness sunlight at different times of the day without disrupting sunlight from accessing the interior space though a radiation analysis that measures kilowatt hours per meter squared (Khpm2). The collection changes in panel elements of the façade in various position, orientation generated from Rhino grasshopper are then compiled into a sequence through unreal engines animation tool that can be triggered to move in relation to another object and function in the virtual world which simulates the animation of the system in relation to the suns position and intensity which becomes a virtual animated model. This animated virtual model created in the game engine can constantly be edited to improve performance through immersive experiential design and alterations of the forms generated in grasshopper. The task of simulating and designing models that are performance based is challenging and requires constant Adjustments. We explore the possibility of using a virtual reality model as a potential alternative for physical simulation models that require constant alterations to reach the desired design properties for complex kinetic motion facade.

Keywords –

Kinetic system, performance-based design, digital simulations, design considerations, simulation.

1 Introduction

Building facades perform various function such as such as ventilation, daylight management, interior providing convenience for users, energy saving and information display.

Recently, there has been an increase in the interest of users and designers in Kinetic facades as a solution to problems that arise in the buildings and cities. Technology has played an important role in innovation and increased performance of Kinetic facades to respond to climatic problems that could not be solved by the conventional static façade.

Computational simulation tools and 3D modelling grant designers the ability to creatively simulate and experiment on various forms, structures and materials, while considering environmental factors such as climate and use real time-data to design building skins that are intelligently perform required task such as improved daylighting, shading, displaying aesthetic information, and movement as required.

Kinetic facades combine mechanical electrical and often sensor devices into the building skin that creates the behavior of the building.

To achieve the desired results for kinetic façade design there various design decisions that need to be made from conceptualization to maintenance of the façade. As kinetic facades are complicated based on the task they are required to perform. Early decisions need to be explicit and precise as mistakes made from the early stages further get complicated in later stages of the design process and can lead to facades that perform below the required performance standard intended by the designer.[1]

Even though there has been a constant development of computational simulation and 3d modeling tools there are still limitations that hinder the creative expression and

innovation of kinetic facades such as motion simulation and user convenience experience. Previous researches conducted on Kinetic façade design presents that most users create physical scale models in early design stages to experiment and analyze design concepts and ideas. This can be a tedious process as physical models need to be constantly altered to achieve the desired result.

Virtual reality technology is a possible solution to test and analyze the performance of Kinetic models. Recently Game engines have been used to create various architectural projects and have become a pivotal tool for communication in the Architectural engineering construction (AEC) Industry. Functions such as real time rendering, lighting, shading, collision detection and animation are important for rapid prototyping and interaction of digital models that are dynamic in nature which allows users to make more efficient and accelerated decisions that could not be made through the means of physical models. Although Game engines are a beneficial tool for rapid prototyping of kinetic models, as a standalone game engines cannot perform required measurement of performance required. The required performance and expected behavior need to be based on the modelling and climatic that are compatible with real world data

2 Background and Related Research

There has been a substantial amount of research concerning the geometric forms, technology, and fabrication of with little research allocated to the motion. A composition of multiple elements of a kinetic façade have to create a pattern that can remain in constant motion to achieve the required expected motion behavior.

It is not enough to see architecture or interpret it based on drawings; the experience of a built environment reveals the collection of all design decisions. Virtual reality has the potential to provide the AEC professional with the ability to experience the project designs before they are built. With benefits such as immersion and interaction that can be achieved at a higher level in virtual models than physical models. A research conducted by Siitonen used and compared a walk-through VR and an endoscope-photographing model method, and verified which one was better in manipulation, lighting and spatial reasoning capacity through visual observation of outcomes and interviews with participants with VR the most accepted tool. [2]

Game engines have a physics that is based on physical systems to provide approximate simulation, such as rigid body dynamics (including collision detection) that is important to the scope of this paper to simulate the motion of the geometry.

Dynamic animation in game engines allow the simulation of various assets in the game individually as

required. They can act collectively or based on individual object oriented animations that collectively become a system patterned of motion.

Adaptive façade design aim at creating strategies for designing facades to respond to environmental conditions, various factors are to be considered but in this paper we focus on motion that can optimized to create shading for the building and harness sunlight at the same time. Adaptable architecture is described for the first time by Frei Otto as a system that is able to change of shape, location, utilization, or spaciousness.[3] The lighting and shading system of game engines allow the user to immersive experience kinetic with a high degree of realism.

Based on the typology classification by F. Otto Mechanical movements can always be reduced to basic types of movement: Rotation, Translation and a combination of the two. [4] Rotation was the selected motion to analyse in this paper.

For kinetic facades, the main considerations in delivering viable plans are automating and active arrangement with comprehension of kinematics, development of recreation, dependability and toughness are the keys to fruitful execution of kinetic elements in structures. These components are concurred by the greater part of the planners and designers when managing dynamic facades. Essentially, the behaviour of the simulation and kinetic motion patterns and what capability of the mechanical essential as the understanding will impact the expected execution of the kinetic facades.

In moving in the direction of utilizing the style and productivity of game engine shading functions, we asked "what can be a data generated comparable base to the virtual model? Furthermore, "What aspects of kinetic motion can be studies in a virtual model?" which presented the required tools for this research as Rhino grasshopper and unreal engine 4.

3 Methodology

3.1 Approach

The proposed experimental process of modelling and simulation considers two main factors that are important in the design for the scape of this research.

1. The optimization of the kinetic faced based on climatic data especially illuminance annual daylight of the interior space
2. Visualization of the kinetic system's motion in virtual reality with special concentration on day light intensity and shading from the façade design which can be an immersive experience in virtual reality.

There are limitations to the function animation of geometry in game engine virtual space based on real world data. So in this paper we consider a simple vertical upward and downward motion of the building cladding to provide sunlight and shading to the interior space as required. Absolute prediction and mimicry of the behavior of kinetic motion of facades that can be applied to real world buildings in a game engine simulation is a challenge and most likely an ineffective method at the current time so the scope of this paper is limited to conceptual design decisions using the combination of data generated from an optimized model and animation functionality of VR game engines to create innovative design concepts and solutions. As seen in figure 1.

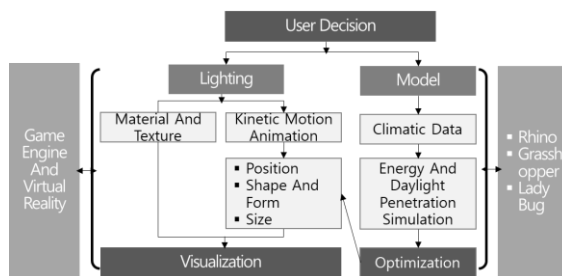


Figure 1. Overall Flow of Research

3.2 Kinetic façade optimization

The performance of the kinetic façade was measured using Ladybug grasshopper plugin. The cladding is a simple hanging cladding at the bottom and top of the curtain wall that shades the building as it rotates upwards and downwards. Both claddings rotated as a mirror of the cladding. Computing for multiple levels presented inconclusive results. So the simulation was conducted for a single floor. Four simulations were conducted in relation to motion. The Climatic data was real world data of Incheon, South Korea downloaded from an open source.

1. The Static mesh averaged 626.5 kWh/m² and the annual daylight was concentrated around the windows of the space.
2. Introducing the cladding without any rotation the annual daylight averaged 783.9 kWh/m² and the lighting concentration was even all across the space due to the replacement of windows with a curtain wall.
3. At rotation motion of 15 degrees of the cladding the annual daylight averaged 506.8 kWh/m² and the lighting concentration was most concentrated at the rear end of the space.
4. At rotation motion of 20 degrees of the cladding the annual daylight averaged 469.9 kWh/m² and the lighting concentration was generally dimmer than

previous iterations.

Further simulations presented results that were either too bright or too Dim, which presented the acceptable range of rotation motion of the cladding to be from 0 degrees to 20 degrees. The annual daylight simulation was programmed using the ladybug plugin as shown in figure 2.

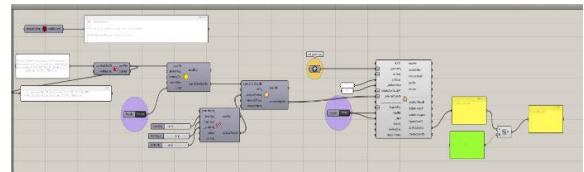


Figure 2. Ladybug grasshopper simulation using real world climatic data

3.3 Game Engine Animation system

The animation of the kinetic system in the game engine was created using a visual language system called blueprinting. The entire movement was controlled by the blueprint which remains constant through the entire simulation excluding the angle of rotation that needed to be changed after every run of the animation as seen in figure 3. Considering that the motion was the purpose was to provide insight into the motion of the cladding, the simulation was run at different animation speeds and durations that are easily customizable after each animation run. Every cladding had its own animation blueprint which made the animation of every element independent and made it possible to run the animation of any single geometry possible when required.

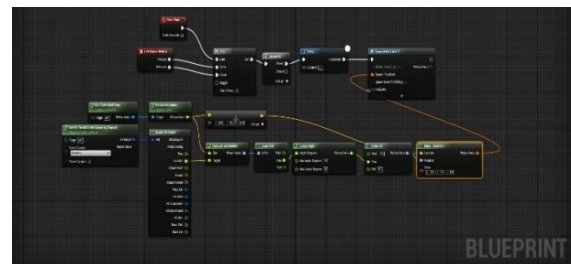


Figure 3. Rotation animation blueprint

3.4 Virtual Reality Experience

Through Virtual reality executables we were able to experience the lighting, shading and motion in immersive VR as seen in figure 4. And shading created by the kinetic motion of the cladding in real world scale and as a small scale model. Through virtual reality controls, aspects of the kinetic façade were edited or turned off to help the user understand how other movements can be changed. A limitation of this process was the complexity of the workflow that made it difficult to make changes to

the virtual simulation in real time.



Figure 4. Immersive VR experience of the Kinetic façade motion

4 Results and Assessment

The results of this proposed workflow that incorporates Rhino as a simulation tool and unreal engine as an immersive VR game toll presented the following results as seen in figure 5.

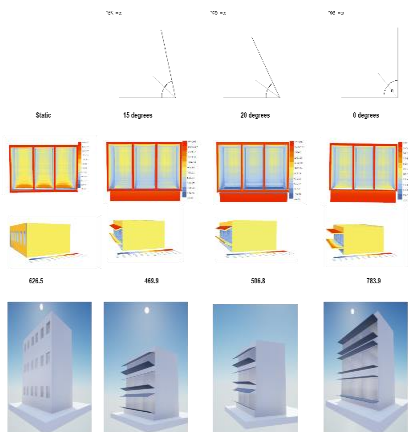


Figure 5. Results comparing the data and model of the Daylight simulation and Game VR motion

1. The game engine lighting and shading were consistent with performance simulation models which makes light and shading studies through the VR game engine effective and convenient.
2. The dynamic nature of the motion of the kinetics elements changed the level of lighting intensity in both the performance model and virtual space thereby altering the comfort of the space.
3. The Immersive animation conveyed the experience of the performance simulation explicitly compared to a third person view of the 3D model

5 Discussion and conclusion

The behavior if the kinetic of the kinetic motion that was required in this paper was simulated using a real

world data compatible simulation tool which is an important as designers of kinetic structure must consider performance

The potential for game engine VR to be a toll for modelling complicated kinetic structures is possible but requires the user to have an in depth understanding of game engines or VR software which can make the process of integrating such method of modelling kinetic systems apprehensible for constant use.

VR game engines are potentially alternative modelling tools as any errors or mistakes enquired during the performance simulation in Rhino grasshopper were adjusted and re integrated into the animation blueprint which would have been a more complicated and tedious task in a physical model

We acknowledge that this research is basic in and simplified in in the demonstration of the convergence of performance based model and virtual models. Our Further research intends to address more complicated geometry, structures, mechanics and materialism

The proposed process can be an important way forward for designers to innovative create kinetic modes that perform based on real world data in a convenient workflow.

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