An Agent System Based Tool to Help Designers for Free-Form Shape Generation in Digital Media

Mahmut Cagdas Durmazoglu, Arch.
Institute of Science & Technology, Architectural Design Computing Graduate Program, Istanbul Technical University, Istanbul, Turkey
e-mail: cagdas.durmazoglu@gmail.com

Prof. Gulen Cagdas, PhD., Arch.
Faculty of Architecture, Istanbul Technical University, Istanbul, Turkey
e-mail: cagdas@itu.edu.tr

Abstract

Architects have to search their design solutions back and forth through several abstraction levels to create the final design. But sometimes designers have to take one more step further in order to achieve the resemblance between the intended result and the end product in the domain of free-form design. Visual simulation models in digital environments of the designs are important tools for architectural process, but without any proof about whether the design could be built or not, these models are not enough to determine the design's feasibility. Therefore, designers need a tool that would work with them to determine if the design could be build or not and how could they improve their design solutions.

The aim of this paper is to find answers to the "how an agent system based tool can help designers for free-form shape generation in digital media?" question. The main issue about this problem is defining the main areas that agent based tool will be used to help designers. These areas should be determined by examining the difficulties within the domain of free-form design. Although there are several difficulties within the domain of free-form design, such as difficulties concerning the structural characteristics, materials and the form-finding process; this research only focuses on the form finding process regarding free-form design.

Form finding process of the free-form design is mainly depended on the distribution of the forces. How the forces distributed along the structural system and whether the design meets the structural stability or not, are the critical questions that define the form finding process of the free-form design. There are not many practical ways to determine if the design is capable of baring these forces or not. One of the most practical among the approaches is using the rain-flow analysis method to test the performance of the design solution under these forces.

In order to do that, design should be modelled in some suitable modelling software. After the design solution imported into the modelling environment, the design should be analyzed with the rain–flow analysis method. After the simulation and analysis is finished, the agent (in our case one of the completed agents) searches through the design and suggests alternative design solutions or points out the problem areas within the design according to the results of the rain- flow analysis.

Keywords: Agent systems; free-form shape generation; rain-flow analysis; simulation models; performance analysis.

1. Introduction

We are not entirely unfamiliar with the use of computer as architects for a long time. Architecture and industrial design firms have been using computers aided design programs for more than a decade and that technology is advancing aggressively since then. However unconventional use of dynamic modelling software and animation applications in architecture and industrial design is a rather recent event compared to the time we spent using computers just for their drafting abilities.

Architects like Ben Van Berkel and designers like Karim Rashid have placed themselves in another plane, completely different from the rest of the practitioners with their novel choice of using software which was intended for making of special effects and computer game development in the first place, to represent their designs in unique ways beyond the potential of traditional CAD software. Computer has been taking a bigger part in the design profession because of its ability to enhance efficiency in the process and for its remarkable flexibility as an artistic instrument in design. We can see computers' growing effect on architectural design with Greg Lynn's statement in which he has explicitly admitted this increasingly symbiotic relationship between designer and computer during an interview in 1998. Greg Lynn stated that "If it comes down to it, I would have to give the software 51 percent of the credit for the design of my buildings." [1].

Free-Form Architectural design could be mainly described by designs of different international design groups and firms like Gehry Partners, Asymptote, Decoi, Eisenman Architects, Greg Lynn Form, NOX, Mecanoo, UN Studio, Oosterhuis NL, VVKH Architects, Foreign Office Architects and many more. These firms have made remarkable contribution to the creation and illustration of the new architectural morphologies, different design strategies, documentation and explanation of the processes with their both constructed buildings and yet to be realized designs. After the construction of Gehry's 20th century Guggenheim Museum in Bilbao, there has been a tremendous change in the perception of architecture, it evolved into something completely unique by means of novel geometric and digital approaches in architectural design. Moreover, domain of free-form architecture has found its place and architectural form which was only produced digitally before, began to appear more frequently not just on the screen as impossible designs which would never be built, but also on built environment with the help of new computerized techniques that Guggenheim introduced.

Publications in the field are highlighting the principles, theories and methods concerning the subject on individual cases. They provide a solid foundation for the up and coming design content and have a large impact on the design theory. Nonetheless there is not enough number of researches about dynamics of the design process of free-form architecture and its limitations. Any designer who has limited or no knowledge about the limitations which gives the design artefact its final shape, like limitations about material, structure etc., bound to spend considerable amount of time while deciding the form of the building and might have to compromise some elements that are crucial in the context of their design just to make their design feasible to realized. Therefore, exploring the possible limitations concerning this emerging field and developing a tool to help designers to successfully solve problems that occur because of these limitations and optimize the design is crucial and the focus point of this research.

The main motivation to start this research has been to develop a model and a prearranged framework, which is capable of outlining the knowledge about the design and production phases, and some difficulties in this domain. The reason behind developing such a framework is to have it as a foundation of the future work related to the design tool we propose. By successfully and clearly outlining and describing the problems in the design process of the artefacts which belongs in the free-form design domain, making necessary additions to the existing design tool in the future would be possible and a lot less time consuming. Thus, we focused on pointing out the possible problem areas within free-form design domain while developing the tool capable of dealing with at least one of these difficulties. This research aims to be the next step of this exiting evolution and try to set out the principles of the design tool, which would act as a colleague to the designer by interacting him/her with the means of sharing of ideas and pointing out the problems.

In the research the main technique used to determine whether the geometry of the free-form design is feasible or not is the rain-flow analysis which is simulated in computer environment. Rain-flow analysis is used for searching the relationship of form and force in (irregular) curved surfaces. This idea was borrowed from a research made by Andrew Borgart, March de Leuw and Pierre Hoogenboom. Bogart, de Leuw and Hoogenboom stated that, "Like a rain flow loads will flow along curves with the steepest ascent on the shell surface to its supports."[2]. This hypothesis for the flow of forces in shell structures was used to determine the feasibility of the free-form surfaces according to three design flaws:

Loads on the free-edges

Bending moments

Drain curves (valleys)

2. Free-Form Design

Architects have always been wanted to achieve to an aesthetic state, which can be explained by the irregular curves that used to describe free-form architecture and the unusual geometric approach, which was used in the process of producing these -almost liquid- forms, throughout the architectural history. This disposition can easily be seen in the examples of different architectural eras, such as; decorative, flowerlike forms of Art-Nouveau, nested/immersed style of Baroque architecture and the organic design repositories of twentieth century. In addition there is a new generation of architects, whom does not afraid of ever being tentative, emerged with not so different themes and forms that 1960's neo-avant-garde dealt with, almost thirty years after the generation of Archigram had introduced their unlimited capacity of imagination to the world of architecture with their walking cities and utopian environment scenarios [3].

By means of recent developments in the computers and their ascending use in architectural design, there have been serious innovations in the domain of architecture: digital free-form architecture had become seen frequently than ever before and the construction techniques have increasingly become products of computerized procedures with the benefit of recent use of digital computer technology. Nowadays computers are not just used as drawing tools like t-square in the design process as they used to be, they have taken place in almost every phase of the construction process. They had found novel ways of usage in the design process concerning form, structure and planning. Computers can also assist the designers in construction phase. As a result of that most of the contemporary designs are computer generated or about to emerge as a result of the implementations of latest computer hardware and software. Nevertheless, architectural form has reached a fascinating state with the rising number of applications that computers have found in the design process with new techniques such as CAD (computer aided design), CAE (computer aided engineering), CAM (computer aided manufacturing) and CNC (computer numerical control). With the aid of computer animation software, designers can master complicated forms which consist of irregular curves that they ever dreamed of.

Working methods in designing free-form buildings can easily observed by examining the works of the pioneers in the domain. As common knowledge, Frank O. Gehry designs his shapes manually working on mock-ups of the buildings than produces a 3D model with the use of scanning the final shape with 3D scanner. On the other hand, Greg Lynn and some others entirely depend on software during the design process.

In our approach we propose “tool” – in the sense of a program component - consists of an agent system embedded within the software to analyze the feasibility of the form of the design.

3. Agent Systems

Agent-based computing started in the 1970s, and in the last years the notion of agents has become important by their intensive usage in the internet applications, drawing ideas from Artificial Intelligence and Artificial Life. Although there is no universal definition of the term agent, in the context of computer science, agents can be defined as intentional systems operate independently and rationally, seeking to achieve goals by interacting with their environment [4]. Agents have goals and beliefs and execute actions based on those goals and beliefs [5]. These features set apart a rational agent from the computational agents that perform actions based on predefined events, like search agents on the web.

Agent systems mainly have a usage in the field of architecture as intertwined with the implementations of virtual worlds. When searching through the literature to find the documentations and examples of usage of the agent systems related to the architecture, one definitely came across the rich body of work about; agent approach to sharing and synchronising building model data among CAD and virtual world systems, agent models for 3D virtual worlds, design agents for 3D virtual worlds , situated agents, creativity in design, situated computing, multidisciplinary design in virtual worlds by mostly done by Mary Lou Maher[6-7], John S. Gero[8], M. Rosenman [9] and R. Sosa [10].

Another usage of agents in the architectural design is in the field of decision making. Designers use modelling and generative tools to produce a model of the designed artefact which other tools simulate the behaviour of the model within the same shared representation. Such design environments are typically described as multi-agent decision making environments.

Aly has investigated enhancements to the design of computational assistants in multi-agent design environments that use shared representation schemes. He proposed expanding the notion of agency to the design objects; these agents than interact with other agents in the execution of design tasks relating to the objects. This approach called objects-as-agents approach, where objects are selectively activated to participate in decision making sessions to execute tasks regarding their immediate design states [11].

An object-agent (OA) is a design object that is activated to perform tasks. In an OA-based design environment, domain applications are global problem solving nodes, OAs are local coordination and management nodes, and, collectively, the designer(s) act as a coordinator and final judge. The designer orchestrates this fine-grained agent environment through incremental interactions until the model arrives as an acceptable design state [12].

We share same the point of view with Krishnamurti and Aly regarding multi agent decision making environments. The agents we use in our tool have object-agent behaviours. They separately activated to perform certain tasks in the model; in the model we propose one of the object-agents only deals with the rain-flow analysis on the form and another one is responsible of the visualisation of these results.

4. DigiTool

This research tries to explain "how an agent system based tool can help designers for free-form shape generation in digital media?" The main issue about "developing an agent based tool to help designers for free – form shape generation" is defining the main areas that agent based tool will be used to help designers. These areas should be determined by examining the difficulties within the domain of free – form design. Although there are several difficulties within the that domain, like difficulties concerning the structural characteristics, materials and the form – finding process, this research only focuses on the form – finding process .

The form finding process of the free - form design mainly depended on the distribution of the forces. How the forces distributed along the structural system and whether the design meets the structural requirements or not, are the questions that define the form finding process. There are not many practical ways to determine if the design capable of baring these forces or not. One of the approaches to determine whether the geometry of the free-form building is feasible or not, is using the rain flow analysis to test the building's performance under these forces. Rain-flow analysis is used for searching the relationship of form and force in (irregular) curved surfaces. The idea borrowed from a research made by Andrew Borgart, March de Leuw and Pierre Hoogenboom. Bogart, de Leuw and Hoogenboom stated, "Like a rain flow loads will flow along curves with the steepest ascent on the shell surface to its supports." [2]. This hypothesis for the flow of forces in shell structures was used to determine the feasibility of the free-form surfaces according to these three design flaws.

One of the main objectives of this research is to develop an agent based tool to help designers in free – form shape generation which used the rain flow analysis to determine the feasibility of the form and suggest different design alternatives which meet the requirements or help designer to revise their design according to the these results. In order to do that, design should be modelled in some suitable modelling software. Designers could use any surface, which modelled in a compatible modelling program to run rain-flow analysis. After the import or modelling phase, original surface should be duplicated and placed above the initial surface to use as a source in which particles emit from. After defining the gravity and amount of resilience of the particles, particle type, line and tail widths which could be modified within the program in order to enhance the visibility of the particles during the simulation. These groundwork phases before the actual simulation could be taken a lot of time if someone tries to do it by hand. In order to control the whole simulation and the variables, a script that actually does all these actions is written. In the later versions of the tool, designer would be able to change some of the key parameters with a user interface. After the simulation / analysis is finished, the agent (in our case one of the completed agents) searches through the modelled form and suggests design alternatives or points out the problem areas of the design according to the results of the rain flow analysis (Fig.1.).

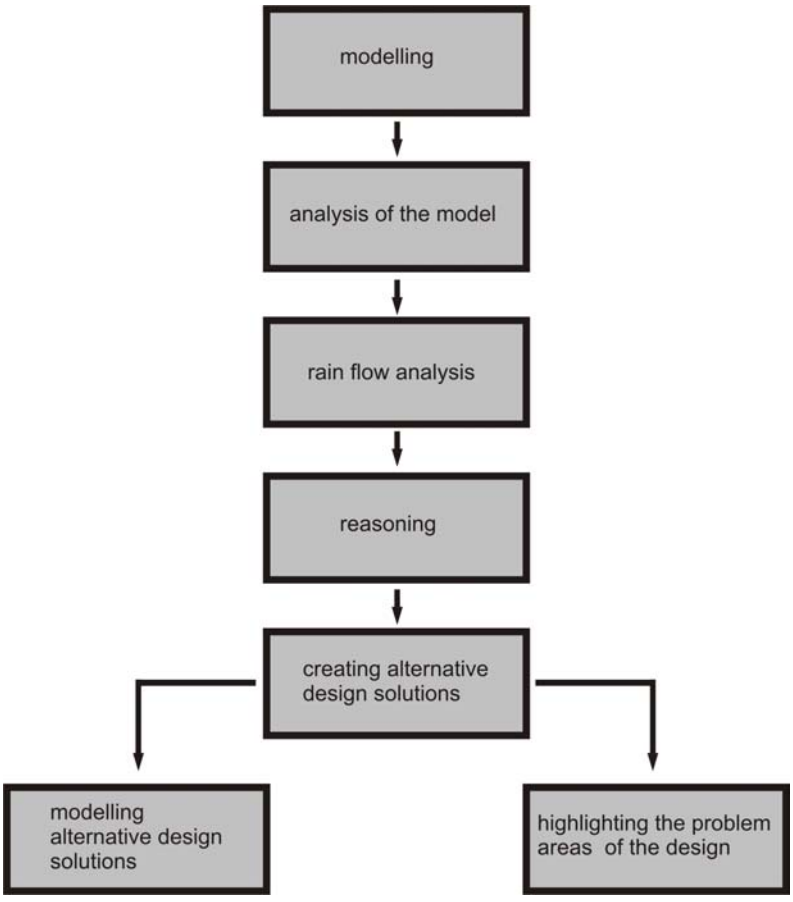

Fig 1. Workflow diagram of the tool.

Different types of agents considered to develop at the later parts of the research. All of these agents would be planned to be act as an individual tool that helps designer to develop their design in the domain of free – form design. Each agent would be specialized in the different problem domains. These agents differ from each other by their behaviour types. Analysing agents analyse the model before the rain flow analysis and recognize the objects in the model by their attributes, and names. Some kind of standardization in modelling process should be made in order to analysis agents could work properly (using predefined colours and names for some objects in the model). Reasoning agents work on creating alternative design solutions according to the results of the rain flow analysis (these results could be made understandable for agents by using colour). They could define the problem areas of the design and reasoning about how these problems should be solved. Suggestive agents could help designers by suggesting alternative design solutions according to the result of analysis. Modelling agents could help designers by visualising the alternative design solutions, that reasoning agents provide, based on the initial design. Computation agents could help the designer by converting their initial surface element into the means of parametric design and providing alternative surface component solutions based on the material of the component or the shape of the component. One or two agents with various behaviour types planned to be developed for during the research.

In order to test the tools reliability, some selected building examples tested out according to previously mentioned design flaws regarding to free-form surfaces.

4.1 Case studies

Eero Saarinen's Kresge Auditorium in MIT campus is chosen as one of the case studies to test the reliability of the tool we proposed (Fig.2).The reason that we chose the Kresge Auditorium to be one of the examples that tool would be tested is that Kresge Auditorium is not considered as one of the successful examples of the shell structures. Because of its geometry the forces on the surface could not entirely distributed along the surface, and it resulted with the cracks on the surface. Because of these faults, Kresge Auditorium does not look like as it designed in the first place – thin white a concrete shell. Instead it was coated with lead panels to cover its concrete surface.

The Kresge auditorium defined by a thin shell structure, one eight of a square approximately height of 50 feet (15.24 meters) and divided by translucent glass walls so that only three points of the shell structure touches the ground [13].

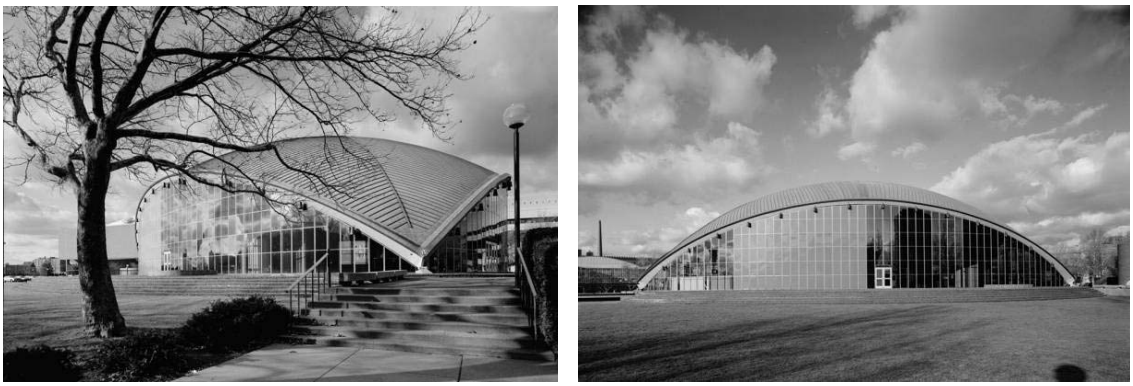

Fig.2 Retrieved from http://en.structurae.de

Dimensions of the Kresge Auditorium are calculated by a mathematical equation (Fig.3). Then the auditorium is drawn in a drawing program to check these calculations (Fig.4).

$$R = H/2 + r^2/2H$$

Fig.3

Fig.4

Kresge Auditorium is modelled in modelling program after the completion of the drawing of the Kresge Auditorium in an architectural drawing program. The modelling of the auditorium is made by Boolean operations like substraction and intersection. At first step, a sphere with a 46 feet radius is created, then seven/eight of this sphere is cut and sliced away from the rest. Then three intersected cylinders created in order to have the shape of the auditorium. After each one of the cylinder's and one eight of the sphere's intersection is taken, the final shape of the Kresge Auditorium was completed in the modelling program (Fig 5-7).

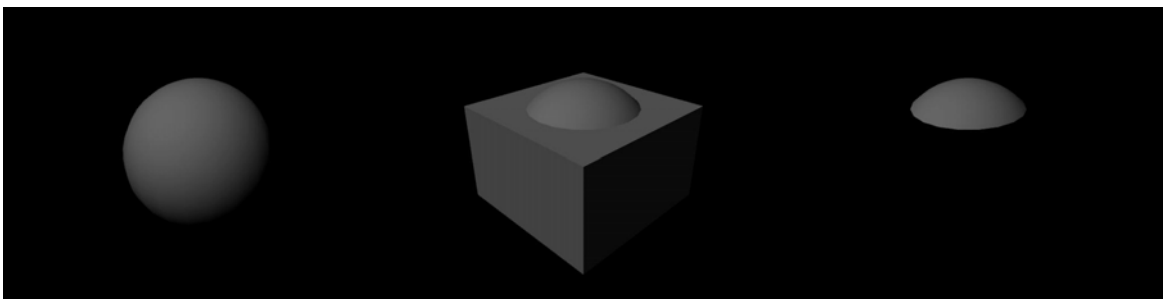

Fig.5

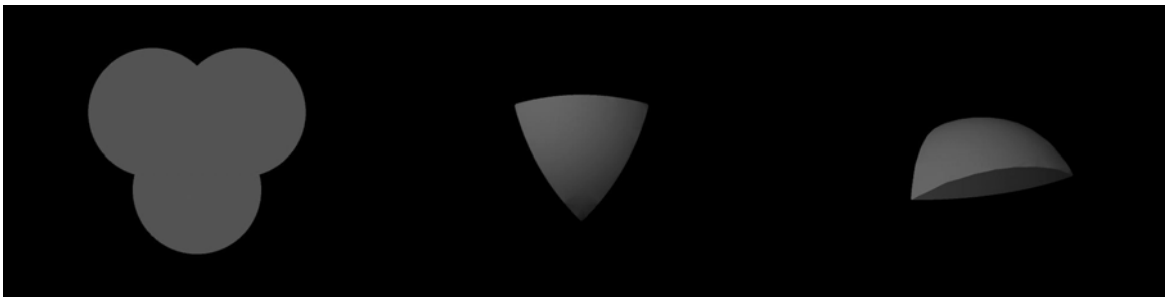

Fig.6

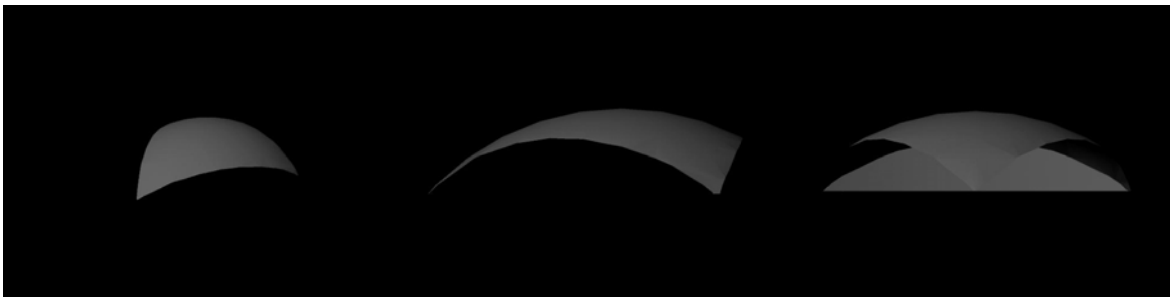

Fig.7

After Kresge Auditorium was transferred into the environment, rain-flow analysis was run with the model of the auditorium. Because of the scripting of the tool was in development process at the time, only the results of the rain-flow analysis could be presented (Fig.8).

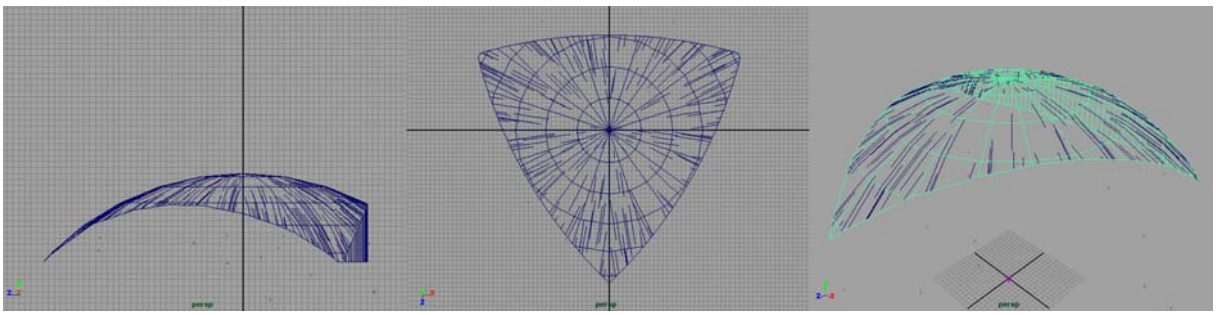

Fig.8

The hypothesis has been tested on the Kresge Auditorium, and the flow of the forces on the surface can be as seen in the results of the rain-flow analysis. On both left and the right sides of the surface, loads run through the edges instead of along the supports. This state leads to an undesirable position.

5. Conclusions

The digital tool we proposed in this paper shows how an agent system based tool can help designers for free-form shape generation in digital media. Results of this research can result in a novel way to determine the feasibility of the form of the free-form architectural designs. We suggest that with carefully describing and documenting the difficulties regarding the design stage of free-form designs like structural characteristics, material and form finding related issues; the core elements of free-form design, which play a great part in altering the design, can be captured so that we can examine and identify alternative design solutions regarding our design repository within the domain of free-form design. In the future, we aim to develop other agents which would deal with other issues related to the design process of free-form architectural designs; like analysing the form according to the choice of materials or computing the optimal size of the divisions on the surface. This way the tool would gives us a clear and through insight regarding designs.

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