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SMATS: Sketch-based Modeling and Analysis of Truss Systems

Neda Mohammadi[1], Ji-Sun Kim[1], Xianming Chen[2], Jian Chen[3] and Mehdi Setareh[1]

[1] Virginia Tech, [2]University of Southern Mississippi, [3]University of Maryland, Baltimore County, USA

Abstract

The present work intends to introduce a domain-specific sketch method for modeling and analysis of forms and structures concurrently. The approach adopted particularly addresses architects, aiming to provide a natural environment for them to present and appraise structural configurations of different truss systems by means of sketching. This is achieved by developing Sketch-based Modeling and Analysis of Truss Systems "SMATS"; a user interface (UI) which provides an iterative environment, in which structural behavior of the sketched configuration is modeled in real-time. Gesture recognition is applied to extract data for a structural analysis program. The results are then brought back to the same user interface for visualization. Moreover, the interactive environment of the UI allows the user to manipulate the design and observe the outcome of changes on the truss structural behavior. Iterative usage of the method will give architects engineering perspective about the class of structures used here. The approach is intended to optimize the conceptual design of trusses by bridging architectural vision in creating forms and the engineering analysis. It also helps architects gain better understanding of the effect of variation in form on structural behavior of trusses.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Aided Engineering]: Computer-aided Design (CAD) H.5.2 [User Interfaces]: Interaction styles (e.g. commands, menus, forms, direct manipulation).

1. Introduction

Architects live through the world of sketches. Despite the advances in computer aided design (CAD) modeling, architects initiate a conceptual design through physical sketches on paper or a sketchbook. It then goes under careful CAD modeling process to be presented as a structural model for engineering analysis.

Design in terms of engineering is also an iterative process. To create an optimal design, the engineer must develop different alternative solutions, evaluate each one, and then select the alternative that best satisfies the design requirements. One of the principal criterions in engineering design is to maintain forces and deformations of the structure within the acceptable limits. Throughout the design process, the initial concept is usually altered several times. This may affect the architect's intention in terms of the original design. However, if the architects are provided with an understanding of the structural behavior of their conceptual design, they could alter the design perceptively by comparing alternatives instantly during the preliminary design phase. This would facilitate the design process, while improving the architect/engineer interactions. While current state-of-the-art sketch-based UIs can handle the geometry very well, few however address the needs of an engineering analysis and possibility of manipulation simultaneously within the same environment.

2. Sketch-Based Modeling

A truss is a popular structural form broadly used for covering large spaces. It is usually comprised of pin-connected linear elements. Due to the simplicity in truss geometry and load application, the members of this structural system are only subjected to tension or compression.

2.1 Interaction

Sketch-based Modeling and Analysis of Truss Systems (SMATS) is designed to allow the user to sketch and manipulate the sketched configuration of a truss while receiving instant feedback on its structural behavior. The user can draw a 2D truss, assign load and support conditions to the nodes and define member properties. Supports can be assigned to the nodes by drawing symbolic gestures. Sketching a triangle would be conceived as a simple support, and a circle would be recognized as a roller support. The user can also assign load to each node by sketching an arrow aligned with the desired direction. The magnitude of the load can then be increased or decreased through a sliding bar to observe the effect of load on the structure. The user

can create or remove nodes and members, or supports, as well as move the position of nodes by dragging the node locators. Performing each of the stated alterations updates the data for a structural analysis program. Once the data is updated, the user receives instant feedback about the effects of that change on his/her design in terms of structural behavior. He/she can visualize the new results through the color/thickness codes and animation. This gives the user the ability to compare different configurations and optimize the design both aesthetically and structurally. For example; one configuration might collapse under a certain load, but by changing the configuration or adding/replacing the supports condition, the structure would become stable under the same loading condition.

2.2 User Interface

The UI for SMATS provides architects an interactive environment as simple as their sketchbook provides. The user can create the outline of his/her design using a stylus (Figure 1(a)). Software training as it is required for the traditional menu-driven tools is not needed in here. SMATS is a self-training UI where an architect can gain engineering perspective on the structural behavior of forms through using the program iteratively. $1 Unistroke Recognizer [WWL07] is used as a gesture recognizer in order to determine required data for further analysis. Once the sketched truss is recognized by the program, an enhanced version of the model with the standard symbols will replace the sketch. This takes the user to the interaction mode where he/she will have the option to either visualize the behavior of the sketched design under the assigned loads, or manipulate the design to a desired geometry, load, support condition, or member properties.

2.3 Analysis

The behavioral feedback visualization is in the form of color/thickness codes for internal forces members, and animation of structural deflections under the applied loads.

The structural analysis is performed by PC-SAPIV [MAI94] a structural analysis program for static and dynamic response of linear systems. Since sketch-based interface is provided for non-technical individuals (architects), the analysis process is not apparent to the user. Only the visual results from PC-SAPIV will appear on the sketchpad in real-time. Figure 1(b) shows the generated internal forces in each member of a sketched truss under the load using SMATS. The members under tension are colored in blue and compression members are in red. The thickness of each member represents the relative magnitude of the internal force of that member in comparison to the other members. Figure 1(c) shows a screenshot of the animation which represents the deformation of the truss under the specified load and support conditions. Figure 2 shows the possible configurations achieved from the initial sketch in Figure 1 through dragging the node locators.

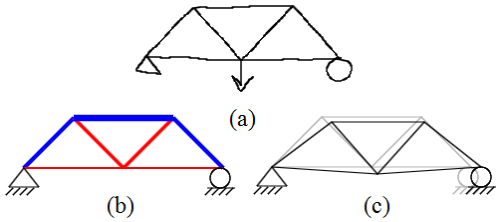

Figure 1: *Behavioral Visualization.*

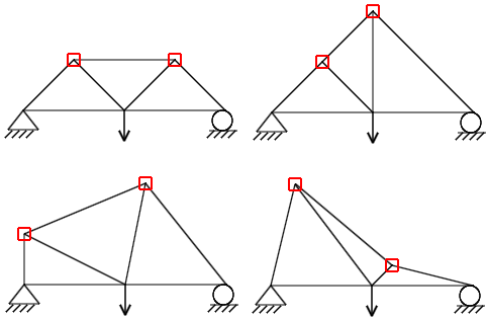

Figure 2: *Interaction mode.*

3. Discussion and Conclusion

The present work is part of an ongoing collaborative research effort in the area of architectural/structural engineering and computer science to develop sketch-based tools for non-engineers to facilitate and optimize the design process. This allows architectural freedom to create forms, and better comprehend their relationship to structural behavior, without the need to learn or concentrate on the software-specific tools. The main contribution of this research is the development of SMATS, a sketching tool for architects, where the structural geometry and properties of trusses are defined by the user. SMATS includes a set of simple and easy-to-use gestures specifically developed as part of the UI design. The main application of the presented software is to facilitate the what-if scenarios using a visual representation of the structural analysis conducted by SMTAS.

References

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