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"One click" cost estimation tool for the design of "form-active structures"

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Abstract

Unreasonable cost decisions often lead to fatal consequences for the partners involved into the planning/building process of the project. Many projects – most of them considered ambitioned, new and promising at the beginning – failed just because of the "cost explosion" toward the projects end, i.e. due to the fact that costs have not been estimated properly during each step of the design. Such an underestimation may present details in a way that is too optimistic to hold in reality. This paper describes an approach to prevent this problem and presents a tool for an accurate cost estimation for the design of form-active structures. This is achieved by combining mechanisms for the user assistance, data analysis and form-finding with the capabilities of extracting and using knowledge about projects already completed/estimated in the past.

Keywords: form-active structures, cost estimation, form finding, design software, support tool, self learning system, architectural quality, design assistance, planning process

1. Introduction

It is difficult to cover all aspects of form-active structures in one single term, however, an adequate definition is given by Engel in ([1]): "Form-active structure systems are structure systems of flexible, non-rigid matter, in which the redirection of forces is effected through particular form design and characteristic form stabilization."

This paper presents a cost estimation tool for form-active structures that is developed to be a part of the existing "Formfinder" software. This software targets designing engineers and architects, and comes in two parts. The first part acts as a frontend to the user and presents a software client for designing, modeling, simulating and dimensioning of flexible structures on a local PC. The second part is not visible to the user and consists of a huge set of project data that is accessible through the client online. This set of experience data makes it possible to retrieve, compare and analyze projects with respect to different attributes of interest.

Our cost estimation approach described in detail in this paper is now a part of the "Formfinder". It incorporates many concepts which can be considered new in the field of form-active, non-rigid structures. Our main goal was to improve the "architectural quality", this intention resulted in a tool that tries to achieve this goal by:

- A tighter collaboration. While mainly being targeted at designers (architects) only, the tool still presents a global insight into the project by reflecting points of view for the main partners involved into the project;
- Being an "assistance" tool. Instead of being run at the end of the design (and producing a value that does not reflect any particular steps), the tool informs the designer about weaknesses of the design steps currently done. This immediate information makes it possible to recognize and correct mistakes as early as possible, therefore reducing the probability of a potential redesign that may come extremely costly;
- Implementing the cost estimation with the intention of reducing the intervention of the designer to a minimum and to provide a tool that is powerful enough to produce estimates that are sufficiently accurate;
- Replacing a human expert by classifying and partitioning available data about finished (or cancelled) projects and to use this knowledge for future projects by identifying and analyzing unusual cost factors.

2. Collaboration

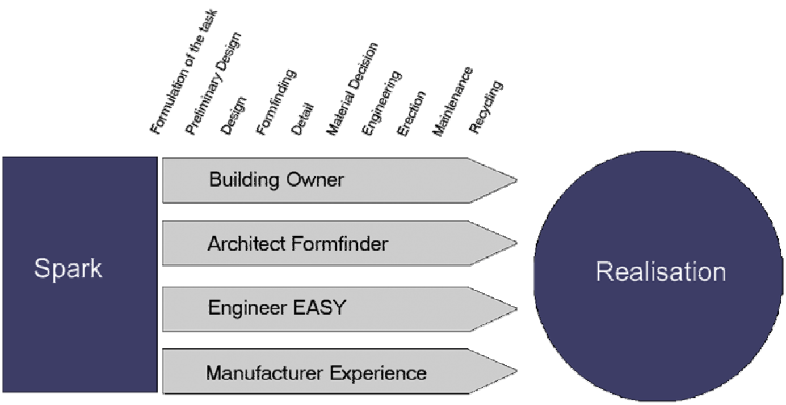

Figure 1: From idea to realization

A proper cost estimation of projects dealing with non-conventional, form-active structures calls for a tight collaboration within the entire team involved into the design- and building process. This team is often multi-disciplinary, spanning a wide range of different specialists.

While working at the same project, each of them may see it differently. For the project to be satisfactory to all involved partners it is therefore important to agree upon a common point. And since design and construction are often driven by the budget, the estimation of the total costs provides a way for such an agreement.

Our tool tries to improve a global insight into the project for the designer. By being organized as a step-by-step assistant, it presents factors and decisions that may be need to agree upon with the partner involved into the current step. So for example, during the material selection, the user is suggested to meet an agreement with the manufacturer about the availability and price of the material.

This of course is not something the designer would not do without the tool. However, this submits the feeling of being a part of a bigger team in a more direct way and forces the designer to check the validity of the agreement regularly.

2. Design assistance

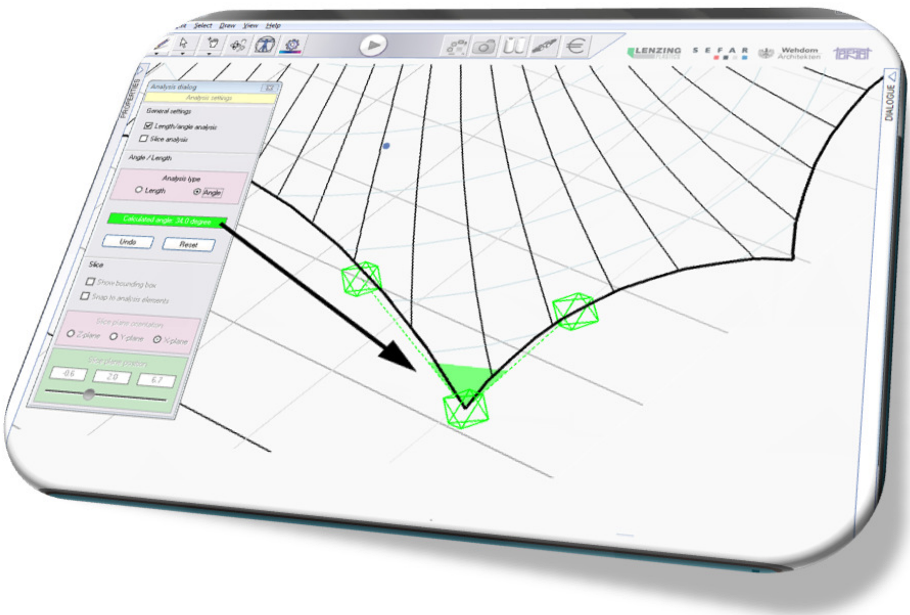

Figure 2: Angle measuring for analyzing the geometry and dimensions

A static tool that performs an analysis and produces estimates after the design has been done has many shortcomings. Localization of design errors is difficult due to the cost non-linearity often introduced by form-active structures. Even if design errors are discovered, they may be discovered too late, making a costly re-design necessary.

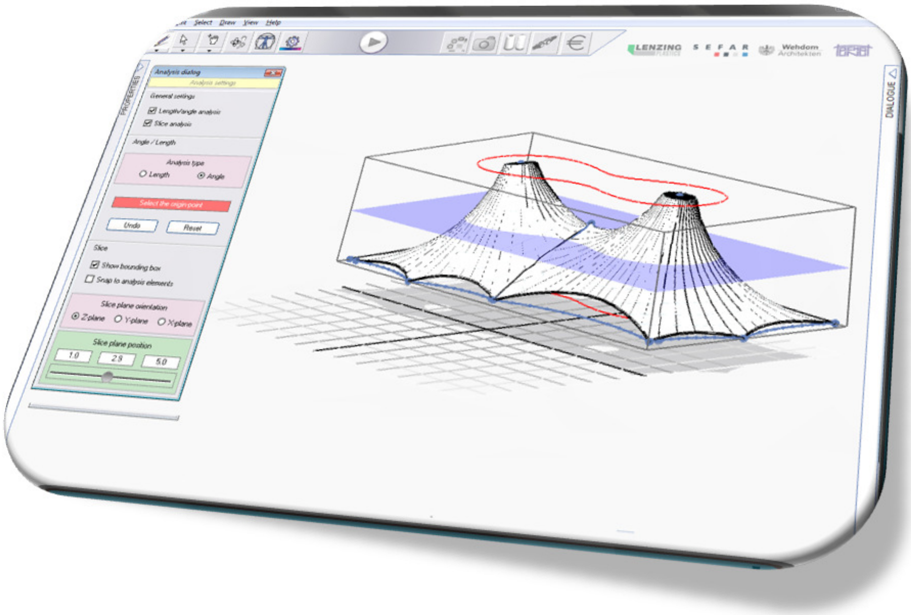

Figure 3: Slice tool to analyze proportions and shapes

Our tool incorporated into the "Formfinder" software follows a completely different approach. Instead of being a post-processing pass, the tool assists the user during the entire design-process. Catching errors as early as possible not only leads to a "cleaner" design and reduces the risk of a potential re-design, but also stimulates the wish for the user to understand things he/she is doing.

By marking elements that appear to be invalid or potentially dangerous with respect to the strength requirements and therefore costs, the user is asked to pay attention and - if necessary - is suggested to correct the errors immediately. This does not only reduce the propagation of errors to the following design stages greatly but has also an important educational meaning. The introduction of a direct feedback to the user may extend its experience at much faster rates and train the recognition of situations when things may go wrong. This educational aspect paired with an intuitive control makes the entire tool much more user-friendly.

Various analysis tools guide the user through the design. Length and angle analysis ensure a proper dimensioning and orientation of particular elements such as posts, edges and corner points. A slice analyzer inspects the shape of the entire structure and delivers important information about the load produced by the wind, snow or rain. A proportion measuring tool is provided to visualize the space parameters of the modelled structure such as height, area or volume in a more obvious and impressive way

3. Intelligent cost estimation

The concept of assisting the user influences the estimation process in a positive way. By rejecting invalid structural elements immediately, the risk of a "cost explosion" is reduced greatly. Further, the estimation is well-structured and progresses step-wise. This simplifies an eventual analysis and makes an understanding much easier. Also, the estimation is design oriented, simple and therefore efficient, producing the result almost immediately. The simplification of the estimating process was done with the intention to address designers only. Instead of analyzing every detail and overloading an architect with complex formulas that are hard and time-consuming to understand and to verify, our tool follows an opposite way and incorporates a transparent behaviour that does not demand from the user to have a doctor's degree in physics.

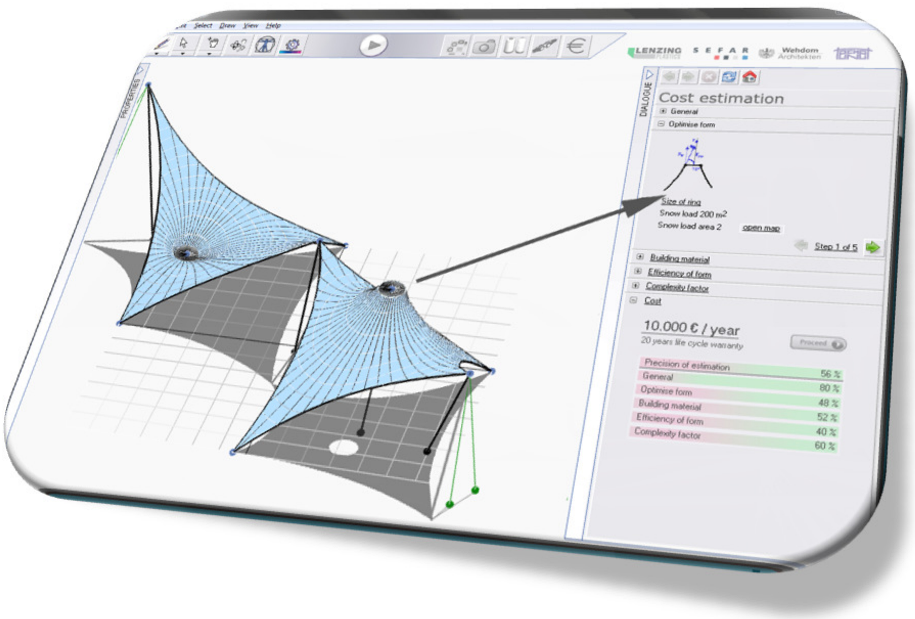

Figure 4: Cost estimation for a highpoint ring

Again, cost estimations made during the design steps are inherently inexact often having deviations from the real value of more than 30%. Our current research shows that despite the algorithmic simplicity the estimations produced by the "Formfinder" are usually more accurate are well below that value for most of the tested projects.

The "intelligence" of our cost estimation has two main components. The first component is responsible for the data extraction from the structure being currently modelled. This static data covers project-dependent aspects such as model geometry, its attributes, and properties of the site with respect to the environmental conditions such as rain, snow and wind. This data is collected through the design steps and at the end fed to the estimator that is used to assign materials and to produce a concrete estimation.

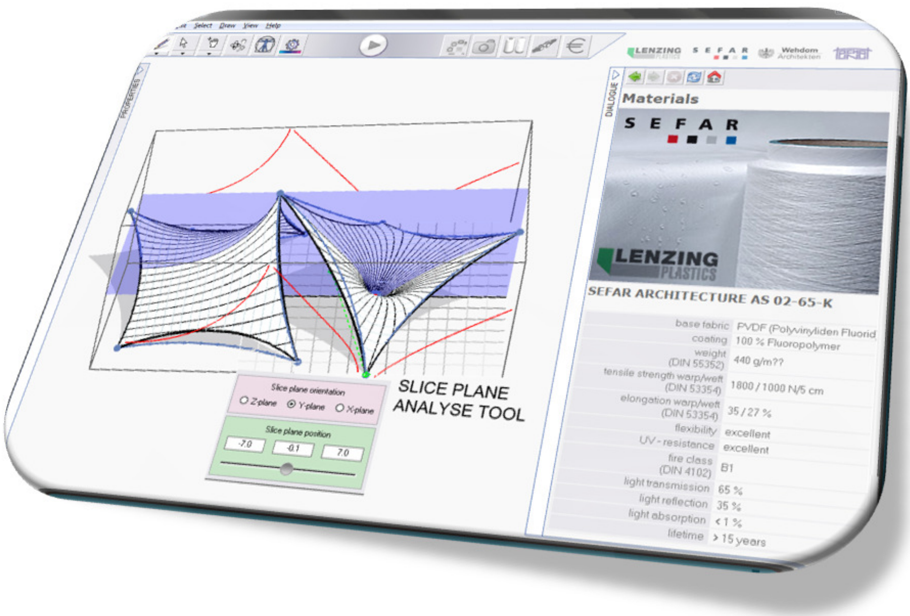

Figure 5: Assignment of materials according to the analysis result

The second component references the experience data. A small subset of most similar projects is extracted from the database according to the static data produced by the first component. The significance of each project within this set is then evaluated. This significance reflects how much the reference project will influence the cost of the project currently being estimated and is a key to a proper cost adjustment. Our experience shows that if evaluated improperly the cost adjustment may degrade the quality of the entire estimation significantly.

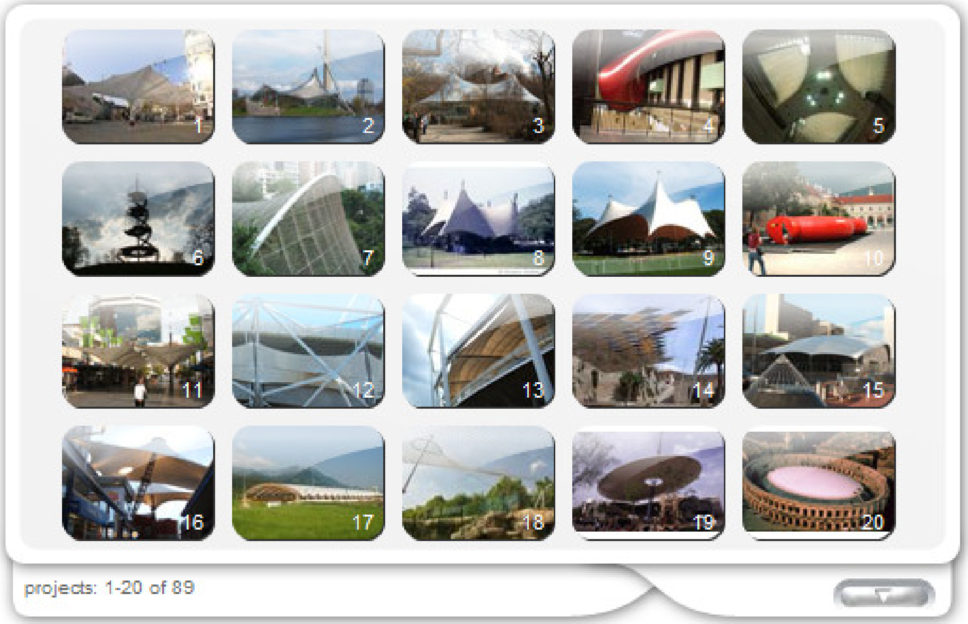

Figure 6: Selection of reference projects for the cost modification

After evaluating each of the reference projects a cost modifier is calculated that is used to adjust the cost estimation produced by the static component.

A static component together with a dynamic, history based analysis seems to be suitable for designs dealing with the form-active structures. The form variety of such flexible structures introduces a vast number of cost factors. Many of them are hard or not predictable at all and can not be captured statically. Here a dynamic component offers an effective help by allowing estimate these factors from the history data. Obviously, the more project data exist, the more effective the dynamic component and therefore the entire cost estimation will be.

4. Conclusions

We have presented a cost estimation tool that supports the designer at producing sufficiently accurate cost estimation during the design process. Conceptually developed to be an assistant to the user, the tool ensures that errors are not propagated to the following stages and therefore minimizes the probability of a cost explosion. By analyzing and evaluating the result during each step of the design the user is assisted to recognize and to correct errors as early as possible. This has two positive effects: cost and time efficiency of the design together with the educational meaning for the designer. To be able to produce accurate estimations, an intelligence component has been built into the tool. Consisting of two parts, this component allows capturing of project dependent cost factors as well as factors that can not be evaluated statically.

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