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The other message of our slogan is "back to command".

In the expanding world of IT applications there is a need for the ready change of preliminary models by using parameters and scripts. These approaches retrieve the feeling of command-oriented systems,

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"The cadence is perhaps one of the most unusual elements of classical music, an indispensable addition to an orchestra-accompanied concerto that, though ubiquitous, can take a wide variety of forms. By

personally selected or invented musical phrases, interspersed with previously played themes – in short, a free ground for virtuosic improvisation."

Edited by Mihály Szoboszlai

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Back to command
Edited by Mihály Szoboszlai
CAADence in Architecture
Back to command

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Faculty of Architecture
Budapest University of Technology and Economics

Edited by
Mihály Szoboszlai
Theme

CAADence in Architecture
Back to command

The aim of these workshops and conference is to help transfer and spread newly appearing design technologies, educational methods and digital modelling supported by information technology in architecture. By organizing a workshop with a conference, we would like to close the distance between practice and theory. Architects who keep up with the new design demanded by the building industry will remain at the forefront of the design process in our IT-based world. Being familiar with the tools available for simulations and early phase models will enable architects to lead the process. We can get “back to command”.

Our slogan ”Back to Command” contains another message. In the expanding world of IT applications, one must be able to change preliminary models readily by using different parameters and scripts. These approaches bring back the feeling of command-oriented systems, although with much greater effectiveness.

Why CAADence in architecture?

“The cadence is perhaps one of the most unusual elements of classical music, an indispensable addition to an orchestra-accompanied concerto that, though ubiquitous, can take a wide variety of forms. By definition, a cadence is a solo that precedes a closing formula, in which the soloist plays a series of personally selected or invented musical phrases, interspersed with previously played themes – in short, a free ground for virtuosic improvisation.”

Nowadays sophisticated CAAD (Computer Aided Architectural Design) applications might operate in the hand of architects like instruments in the hand of musicians. We have used the word association cadence/caadence as a sort of word play to make this event even more memorable.

Mihály Szoboszlai
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Members of our local organizing team have supported this event with their special contribution – namely, their hard work in preparing and managing this conference.

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A General Theory for Finding the Lightest Manmade Structures Using Voronoi and Delaunay

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Abstract: A general theory for finding the lightest possible structures is introduced in this article. Then a special centroid form of the theory is introduced. This special form will later help in the implementation of the general theory itself. The proposed theory applies to any structure regardless of size. The paper examines the special form of the theory on a load case over a cantilevered beam and a shelter structure. The results achieved computationally using the special centroid form of the theory were six to eleven times better than any other available optimized proposed alternative. The importance of Voronoi/Delaunay Diagrams is not only their influential existence in nature but also their ability to adapt to the other possible forms.

Keywords: A search for lightest structure, general theory, special concentric form of the theory

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INTRODUCTION

For all the techniques introduced in this paper, the following tools are used:

• Grasshopper [1]: a visual programming language developed by David Rutten at Robert McNeel & Associates that runs within the Rhinoceros 3D computer-aided design (CAD) application.
• Galapagos [2]: an optimizer component that runs under Grasshopper. It provides a generic platform for the application of Evolutionary Algorithms.
• Millipede [3]: a structural analysis and optimization component for Grasshopper. It allows for very fast linear elastic analysis of frame and shell elements in 3D, 2D plate elements for in-plane forces, and 3D volumetric elements. It produces the initial point cloud.
• Karamba [4]: a parametric structural engineering tool, which provides an accurate analysis of spatial trusses, frames and shells. It is used to find the optimized version of the presumed Voronoi/Delaunay.
• The Delaunay triangulation and its dual Voronoi diagram as in Figure 1. The paper’s aim is to find the points upon which Voronoi/Delaunay would be defined. The aim is to find the optimal Voronoi/Delaunay structural representation based on the calculated stresses of the point cloud produced by Millipede as in Figure 2. These point clouds are the input to our optimization as in Figure 4. This cloud represents the data for the model. Our evolving understanding and interpretation of these points will vary over the optimization process. Our understanding and classification of the cloud represent the knowledge produced by the model. This understanding will prove to be optimal, or not, by using the evolutionary optimizer of Galapagos. A structural engineering tool (Karamba) will be used during the optimization.

THE GENERAL THEORY:
The two main constituents of the general theory are:
A) To optimally classify the point cloud into different zones.
B) To represent each zone by a point, curve, surface, or mass.
An exemplary implementation of the theory is illustrated in Figure 3. The theory is general because it enlists all the possibilities of the zones representations. Though these two assumptions seem simple, the difficulty arises for the theories that implement them. The paper includes an implementation that is based on the centroid method described in section 2.0.

1. THE CENTROID MODEL:
This is the simplest model, computationally and theoretically, to interpret and to understand the cloud. Our understanding of the cloud can readily be proved as optimal or not, as the physical consequent can easily be constructed. We present two methods to understand the cloud. In the first method of analogous systems, optimality is achieved by defining a parallel system that is affected by some of the attributes of the cloud. The applications of this method are the most common of the known structural optimization methods [5]. The second method, which is the paper’s main focus, is the classification method. In our digital testing environment, the classification methods superseded the analogous systems by five to ten times.
Figure 4: An overall representation of the introduced optimization model. The tools used, its rules, and the data/knowledge section are illustrated; the structural optimization and the optimal chord dimensions are summarized.
1.1. Analogous systems (our implementation):

The bounding box of the cloud is divided into equal boxes. The mean of the stresses of the points, inside each of the dividing boxes, is calculated. The values of these means were compared. Based on this comparison, a number of points were allocated to each dividing box. Other exemplary analogous systems can be found in [5].

1.2. Classification methods:

1.2.1. Bell-shaped distribution:

A variation of the normal distribution is used, as the possible skewness of the distribution is of minor importance compared to its computational needs. The chosen bell-shaped Function [1] is more general than the normal distribution. The \(a, b,\) and \(c\) parameters can optimize our understanding of the data as in Figure 6. Galapagos’ main task is to find the composition of these parameters. This would cluster the cloud to produce a local, or global, optimal structure.

\[
F(x) = \frac{1}{1 + \left(\frac{x - c}{a}\right)^{2*b}}
\]  

1.2.2. Machine learning classifiers:

Our earliest optimization effort in this research was to find a mean and a variance that represents each group of the cloud’s points. The hypothesis was that this representation would yield an optimal structure. This effort was found to be a match of the well-known EM algorithm’s Gaussian Mixture’s implementation [6], which is one of the machine learning classifiers. Some of the included machine learning classifiers may be used instead of the bell-shaped distribution or as a final process after the bell-shaped optimization.

1.2.2.1. Hierarchical Agglomerative Clustering:

This method is a computationally expensive method [6]. A binary-tree like data structure is created based on the closest neighbors’ 3d locations and stresses. This method can substitute the bell function [1] in producing initial centers that can later be used by other classifiers. One of the important features of this method is the simplicity of predicting the optimal number of clusters.

1.2.2.2. K-Means Clustering:

The K-Means method is considered the mainstay for our optimization. It must have a centroid guesser for the K-Means calculation process to start. Afterward, each point should belong to the nearest center. After the point clustering is completed, new centroids are calculated, and the process would iterate until convergence.

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1.2.2.3. Gaussian Mixtures & EM Clustering:
The probabilistic Gaussian Mixtures implementation of the converging EM clustering algorithm was the initial focus. We started our classification efforts by implementing similar techniques. It can replace the K-Means algorithm, but with a higher cost.

1.2.3. Discussion regarding the proposed classifiers:
The introduced algorithms could be classified into two groups. The first group, as in Figure 7, is responsible for predicting the optimal number of clusters and a best guess initial optimization. The bell-shaped Function [1] is optimizable, and its local optimizations can be used without any further optimization.

1.3. Chord dimensions’ optimization:
After defining an optimal structure of the general or the concentric theory, the last step in the optimization is to define an optimal dimension for each chord. The chord dimensions optimization enhances structural optimization two to four times. The optimization can be carried out by using Function [1]. The utilization property of each chord of the optimal structure is sorted in ascending order; Galapagos then calculates the proper parameters of Function [1] until reaching the lightest possible structure. This introduced technique can optimally designate different dimensions of any structure type.
2. AN IMPLEMENTATION OF THE GENERAL THEORY:

To implement the general theory, we need to define the optimal classification of the cloud, and their corresponding optimized forms of points, curves, surfaces, or masses.

For implementing the general theory we should abstractly describe our mission as:
1. Our work as an inferring machine. We relate, conclude, re-relate, re-conclude and so on
2. Our knowledge as relations. The most important of which is the relation of classification. Classifications are relations of the relations; a relation cannot exist without the classification relation.
3. The world of actions supports or contradicts our concluded relations.

As in Figure 10, the important constituents of the search are Relations, Hierarchy of relations (relations describing relations, like classification or relations meta-data), Actions, our understanding (tested or untested), and samples of inferred relations (zoom-in-zoom-out, pattern of each zone and its neighbors’ arrangement, form, or stresses). These constituents solely or collectively help to build a best guess.

As in Figure 11, a best guess implementation can be found using the zoom-in-zoom-out relation.

The assumptions are:
• The final clusters’ number is less or utmost equal to the optimal centroid clusters.
• the optimal centroid clusters’ forms are defined using Form recognition techniques
• Low-resolution and high-resolution (using the same bell-shaped diagram) will be used to define the form and then the final numbers of the final clusters.
• The process would perform optimally (computationally) using parallel processing threads.
• Other supportive optimal centroids could be considered to support final decisions.

Figure 10: The abstract constituents of any implementer of the general theory. Computationally, these constituents can function in parallel or sequentially. The yellow colored items represent our best guess general theory implementation as in Fig. 11.
3. CONCLUSION:
What is the difference between the general theory and the analogous system? It is hard to prove the advantage of one over the other, as both can be developed and enhanced to perform better. Both of them are operating based on certain methodology. Our approach depends on interpreting and understanding the point cloud. This approach is readily optimized and controlled. If the analogous systems are designed to rely on the cloud, they will perform better. This proves that introduced general theory is the more general and the more comprehensive approach.

The introduced general theory was envisioned based on the success of the special centroid form. The results, computationally achieved so far, in the concentric form are highly promising, but do not provide a full understanding of the cloud. For example, the form of the cloud clusters may be non-concentric forms and representing them by a point is a misinterpretation. Other possible representations of curve, surface, or masses could be considered as different analytical methods of the point cloud. The abstract constituents of any implementer of the general theory were defined. A zoom-in-zoom-out implementation of the general theory was introduced. This implementation can be regarded as a recursive call to the centroid form.

As a brief of the tests conducted computationally, Delaunay triangulation representation performs two to three times better than Voronoi diagram representation; the Voronoi representation performed much better than other representations like shortest walk, and the classification method, using Voronoi, superseded our implemented analogous method five to ten times.

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