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 designs demanded by the building industry will remain at the forefront of the design process in our information-technology 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".

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.
CAADence in architecture
Back to command
Edited by Mihály Szoboszlai
Editor
Mihály Szoboszlai
Faculty of Architecture
Budapest University of Technology and Economics

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CAADence in Architecture. Back to command
Budapesti Műszaki és Gazdaságtudományi Egyetem

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CAADence in Architecture
Back to command

Proceedings of the International Conference on Computer Aided Architectural Design

16-17 June 2016
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Budapest University of Technology and Economics

Edited by
Mihály Szoboszlai
Theme

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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
Chair of the Organizing Committee
Acknowledgement

We would like to express our sincere thanks to all of the authors, reviewers, session chairs, and plenary speakers. We also wish to say thank you to the workshop organizers, who brought practice to theory closer together.

This conference was supported by our sponsors: GRAPHISOFT, AUTODESK, and STUDIO IN-EX. Additionally, the Faculty of Architecture at Budapest University of Technology and Economics provided support through its “Future Fund” (Jövő Alap), helping to bring internationally recognized speakers to this conference.

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

Mihály Szoboszlai
Chair of the Organizing Committee

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Geometric Modelling and Reconstruction of Surfaces

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Abstract: New technological environment is present in civil engineering and used in academic education. It is also used in geometric research. This paper presents some examples of different technology, used in surface modelling, surface analysis and iterative form finding. By using a 3D laser scanner, a point cloud of a building can be created. Point clouds allow not only 3D visualization, but also further processing. By using CAD software, a surface can be created from certain parts of point cloud. In this paper, an example of this will be presented.

Keywords: surface modelling, CAD, point cloud

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INTRODUCTION
When engineers of today design buildings, they use recent technological improvement: 3D scanning instead of measuring and drawing, a variety of modelling methods, 3D models and BIM. They also use prototyping and reverse engineering. New technologies are also included in today’s education.
The shape of a structure is the basis of every construction project, especially in the field of light structures. Geometry of a surface is of fundamental importance for the behaviour of the structure under load. In the design of structures such as membranes, domes, cable grids, barrel vaults, foldable structures, etc, important areas are also modelling and form-finding process. BIM (building information modelling) requires that all the details of the project are in digital form.

SURFACE MODELLING
Modelling depends on surface properties
Virtual 3D space in CAD can be used as a Euclidean model of the projective space. Surface have to be modelled according to its definition and properties.
Translation surfaces are useful in designing: Part of the surface can be the shape of a dome, over an object. Translation quadrics are cylinders, hyperbolic paraboloid and elliptic paraboloid. Bohemian dome is a quartic translation surface while helicoid can be generated by a helix, translating along a congruent helix [2].
The easiest way to create a model of a translation surface is to translate one (generating) curve along the other (directrix) curve in such a way that a point on the first curve traces the second curve.
Translation surface can be defined as a Minkowsky sum of two curves. The locus of all possible chord midpoints between two given curves is one translation surface (also called midsurface). Conversely, [from the author’s experience [4]]: for a given translation surface there are many pairs of such curves. For each surface on figure 3 such a pair of curves is found using Rhino. Physical interpretation: If endpoints of an elastic thread slide each along its given curve (random mode), its midpoint lies on a translation surface.
Figure 1: Ruled quartic surfaces, modelled using Rhino (own work).

Figure 2: Translation surfaces modelled using Rhino (own work).

Figure 3: Translation surface (left: hyperbolic paraboloid and right: quartic surface) as midsurface of two given curves.
SURFACE ANALYSIS

Shells are curved thin structures, which can take load as the membrane. The thickness $h$ of the shell is small compared to the radius $R_1 > R_2$ of the principal normal curvature of the surface and compared to the dimensions of the object. Shell roofs behaviour depends on the shape of the shell: Shells have compression stresses following the convex curvature while the tension stresses follows the concave curvature. Using CAD software we can observe the normal curvature in any direction, for the considered point of the surface. Curvature analysis offered by Rhino includes Gaussian ($K$) and mean curvature ($H$). Curvature graph displays surface normal and normal curvature along $u$ and $v$ lines of the surface.

Using CAD, it is easy to construct the tangent plane in all points on the free edge of the shell. That is important because supports of the shell are taking only forces in the direction, tangent to the shell.

In terms of the Gaussian curvature [3], shells are classified into three groups:

1. Elliptic surfaces, with positive curvature $K > 0$ form synclastic shells (ellipsoid, elliptic paraboloid and two sheets hyperboloid, elliptic surfaces of higher order).

2. Parabolic ($K=0$) shells with a single curvature, are developable everywhere (cones, cylinders and surface traced out by the tangents of any twisted curve).

3. Hyperbolic surfaces, with negative Gaussian (integral) curvature $K < 0$, form anticlastic (saddle-shaped) shells. Such surface crosses its tangent plane (non-degenerated ruled quadrics). Surfaces of higher order may combine elliptic and hyperbolic regions, which are separated by a locus of parabolic points.

Surfaces with constant mean curvature are useful for modelling some physical processes, including the formation of soap bubbles. Mean curvature vanishes $H=0$ on minimal surfaces, such as Scherk surface. Some other surfaces can have regions of mean curvature approximately equal to zero (marked blue on Fig. 8).
Figure 8: Mean curvature of surfaces: Bohemian dome, hyperbolic paraboloid and Scherk surface (own work).

Figure 9: Catenaries, modelled using Grasshopper (own work).
Rhino plug-in for parametric modelling is Grasshopper. Equal resistance catenary, that was necessary for the exact model of Scherk surface, was modelled in Grasshopper, from the equation.

ITERATIVE FORM FINDING

Different methods are in use within form finding processes. Physical models for tensile structure can be rubber sheet or soap membrane. Using inverse method, the shape that took tensile structure under the load should be turned upward. Numerical form finding methods are iterative. Minimal surface can be modelled for given boundary condition, by iterative method, using Rhino-Membrane, a plug-in for Rhinoceros. On Fig. 11 boundary curve consists of four semicircles. In the first case (red) they were four curves, in the second (blue) concave and convex arcs were connected forming in total two curves and in the last (cyan) case all arcs were connected forming one boundary curve. The result depends on the number of curves.

POINT CLOUD

Using 3D laser scanner “FARO Focus” the theatre building “Teatro Fenice” in Rijeka is scanned. Each 3D image consists of several million points. The integrated camera takes photo realistic colour scans. Point cloud scanned data are processed by “SCENE”, a point cloud software that allows not only 3D visualisation but also meshing and exporting in various data formats for further processing.

SURFACE FROM POINT CLOUD

The point cloud can also be imported into a CAD software and used as a basis for modelling. The result can be presented on the web as a digital 3D model of the object. In this example software Rhinoceros was used for processing a point cloud.
There are several reverse engineering plug-ins for Rhino. One of them is *RhinoResurf*. University of Rijeka has recently purchased a multi-material 3D printing system Connex500. It allows simulation of the final product by combining multiple materials with varied properties and tones.

ACKNOWLEDGEMENTS

I would like to thank dr.sc. Nana Palinić, project manager of the pilot project “Teatro Fenice”, for providing point clouds.

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Figure 15: Surface that was generated from point cloud using Patch command in Rhino and software CloudCompare (own work)
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