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.
Proceedings of the International Conference on Computer Aided Architectural Design

16-17 June 2016
Budapest, Hungary
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 indispensible 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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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.

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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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**REINHARD KÖNIG**

Reinhard König studied architecture and urban planning. He completed his PhD thesis in 2009 at the University of Karlsruhe. Dr. König has worked as a research assistant and appointed Interim Professor of the Chair for Computer Science in Architecture at Bauhaus-University Weimar. He heads research projects on the complexity of urban systems and societies, the understanding of cities by means of agent based models and cellular automata as well as the development of evolutionary design methods. From 2013 Reinhard König works at the Chair of Information Architecture, ETH Zurich. In 2014 Dr. König was guest professor at the Technical University Munich. His current research interests are applicability of multi-criteria optimisation techniques for design problems and the development of computational analysis methods for spatial configurations. Results from these research activities are transferred into planning software of the company DecodingSpaces. From 2015 Dr. König heads the Junior-Professorship for Computational Architecture at Bauhaus-University Weimar, and acts as Co-PI at the Future Cities Lab in Singapore, where he focus on Cognitive Design Computing.

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**BRANKO KOLAREVIC**

Branko Kolarevic is a Professor of Architecture at the University of Calgary Faculty of Environmental Design, where he also holds the Chair in Integrated Design and co-directs the Laboratory for Integrative Design (LID). He has taught architecture at several universities in North America and Asia and has lectured worldwide on the use of digital technologies in design and production. He has authored, edited or co-edited several books, including “Building Dynamics: Exploring Architecture of Change” (with Vera Parlac), “Manufacturing Material Effects” (with Kevin Klinger), “Performative Architecture” (with Ali Malkawi) and “Architecture in the Digital Age.” He is a past president of the Association for Computer Aided Design in Architecture (ACADIA), past president of the Canadian Architectural Certification Board (CACB), and was recently elected future president of the Association of Collegiate Schools of Architecture (ACSA). He is a recipient of the ACADIA Award for Innovative Research in 2007 and ACADIA Society Award of Excellence in 2015. He holds doctoral and master’s degrees in design from Harvard University and a diploma engineer in architecture degree from the University of Belgrade.
Integrating Point Clouds to Support Architectural Visualization and Communication

Dóra Surina¹, Gábor Bödő², Konsztantinosz Hadzijanisz³, Réka Lovas⁴, Beatrix Szabó⁵, Barnabás Vári⁶, András Fehér⁷
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Abstract: Current paper discusses spatial, survey data (i.e. terrestrial laser scanning, structured light scanning, aerial photogrammetry) processing methods and its various use cases from an architect’s point of view. Besides the surveying and data processing, the paper provides details on the topic of collaboration between engineering branches and the power of visualization in communication. Because of the complexity of architectural planning, multiple surveying techniques can be applied to achieve easier and faster project development. 3D surveying technology aids architectural documentation and creates a new way of thinking in handling multidisciplinary communication. Data from different work projects have been selected to demonstrate the flexibility of previously mentioned surveying technologies. The result product can be further used to derive data for architectural purposes, e.g. views, sections or numerical values. The high density point cloud supports virtual/augmented reality applications; both experts and laymen can take a virtual walk, the practical solutions and future options are also presented in the paper.

Keywords: point cloud, terrestrial laser scanning, photogrammetry, architectural modelling, computer aided visualization, architectural documentation

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INTRODUCTION

The HUMANsoft Ltd., a member of 4iG Plc., was founded in 1989, and it is a prominent player of the Hungarian IT market. From its high level services and high quality solutions, the company’s income was 60 million USD (2015), and 300 employees are working for the company.

The HUMANsoft Ltd. founded the Mensor3D Ltd. in 2014. Our main profiles are technical testing and analysis in architecture and mechanical engineering based on 3D scanning.

In Hungary, which is incredibly rich in cultural and architectural heritage, the preservation and digital documentation of the monuments is of common interest. The Mensor3D employs the most advanced 3D technologies for cultural heritage preservation, architectural survey and documentation along with visualization. We make every effort to make products, which are not only for
architects but also for engineering branches, museum, tourist and educational purposes. There are several scientific projects worldwide with similar goals in the field of cultural heritage, architecture, and mechanical engineering. In 2015 Mensor3D Ltd. had the opportunity to scan and digitize Visegrád Palace, one of the 500 sites, which was selected into the CyArk program. CyArk is an international nonprofit organization dedicated to digitally preserve and share many of the world’s most important cultural heritage sites.

SURVEYING TECHNOLOGIES

Nowadays there are several modern, computer supported surveying technologies, which can be used to survey different building elements, whole buildings, sites or streets, city quarters. [1] The following technologies are the most commonly used in architectural survey.

Terrestrial laser scanning

Terrestrial laser scanner (TLS) is a ground based equipment, which measures the position and dimensions of objects with laser light. The laser scanning as an active remote sensing technology is capable of surveying in dark environment, and is not sensitive to shadows. [2]

TLS has become popular for building surveying, because it provides direct, reliable and dense surface measurements in different situations. The terrestrial laser scanner can be used to document one room or even a huge industrial field within centimeter accuracy in 3D. The result of this technology is an enormous quantity of points in space. Each point of this point cloud has an X, Y, Z coordinate and a laser reflectance value, and it can also contain RGB color information, if panoramic images were taken during the survey (Figure 1).

Structured light scanning

Structured light scanner (SLS) is a 3D scanning device for measuring the 3D shape of an object with projected light patterns and camera sets. [3]

SLS is mostly used to document medium or small sized 3D objects or building parts, like entrances, capital of a column and ornaments in high resolution.

Figure 1:
Gray scale intensity colored point cloud (left), intensity colored point cloud (middle), RGB colored point cloud (right)
tion and accuracy. The result of structured light scanning is a polygonal model, a surface mesh, which contains the object’s original color and texture (Figure 2). This mesh is suitable for 3D printing or can be the basis of a 1:1 scale CAD model.

Aerial photogrammetry
Aerial photogrammetry is a 3D documentation technology – in this case the unmanned aerial vehicle (UAV) system – using digital cameras to survey the position and dimensions of objects. One major advantage of the UAV is the small size of the equipment and the decreased on-site measuring time, although it cannot be used indoor. The accuracy and resolution is sufficient for multiple purposes, these are dependent on light and weather conditions. [2]

The result of this technology is hundreds of aerial images, which can be transformed to a point cloud. In this case each point has an X, Y, Z coordinate and RGB color information (Figure 3).

Combined surveying system
Based on the object’s properties, requirements and experience, the surveying method must be chosen after careful selection. Since these technologies have limitations, in order to achieve results faster, with high efficiency and accuracy the combination of different devices and technologies are required. [4]

In the following chapters of the paper, different work projects are discussed to demonstrate this combined surveying systems, its final products and the way how it can help with the visualization and communication.

WORK PROJECTS
Workflow
The laser scanner was used in every work project, the survey with this equipment required the same phases, pre-processing, scanning and post-processing.
During pre-processing the available data were collected from the buildings and sites, the scan positions were planned based on this information. In the beginning of the survey, physical control points were placed to support the scanning, which was carried out from various positions. Where it was required, panoramic images were also taken. During post-processing, the individual point clouds were registered – with control points or cloud-to-cloud method – and colored with the panoramic images. Subsequently the irrelevant data were removed and the whole point cloud was decimated. This data set is the basis for final products, like architectural drawings, visualization.

Ferenc Puskás Stadium

One of the most remarkable projects in the field of digital documentation was the architectural survey of the multi-purpose Ferenc Puskás Stadium in 2014. The scanned data set provided vital information for the partial demolishing and transformation of the building, and documented the Stadium in its current state for posterity. This 3D digitization is the last memory of the original Ferenc Puskás Stadium, because the reconstruction started in March 2016.

The whole building (72,000 m²) had been surveyed from 1300 scan positions for 4 months. In combination with the terrestrial laser scanner (TLS), an unmanned aerial vehicle (UAV) was also used for the documentation. The two individual data sets were combined using physical control points, which were surveyed by total station. [5].

Based on the processed and registered point cloud, the stadium’s architectural survey plan was created, 232 architectural drawings (140 floor plans, 33 sections, 59 facades) altogether. Orthogonal point cloud images were used as a layer under the vector drawings that provided valuable additional thematic information (Figure 4).

With TLS and UAV based digital documentation, the whole scanned building or area is available in a virtual environment, new drawings or images can be easily made without further survey.

One year after the survey, the structural engineers of the stadium faced an unusual situation. In the basement of the main building the pillars were smaller than in the ground floor. Based on the virtual dataset of the stadium, we could make a cross section from the point cloud, which proved that there are differences in the size of the pillars without further survey (Figure 5).

The technology made available to the whole design team (architects, structural engineer, etc.) the usage of the same survey data set, the point cloud, which helped the communication between the members.

Figure 4: Cross section of the tower with orthogonal point cloud image
Prónay castle

The 3D digital documentation of the baroque Prónay castle in Alsópetény, located in the northern part of Hungary was created in 2014. The more than 200 years old castle was renovated and now serves as a hotel and event venue. The whole building (cellar, ground floor, attic, facades) was documented with TLS, UAV was used to complement the TLS datasets and to survey the adjacent castle park. [6] With this technique a very dense point cloud was acquired from the whole site in 2 days. Tie points were used to join the point clouds acquired from different scan positions during the TLS measurements. The two data sets were merged with cloud-to-cloud registration. [5]

After the data processing phase, orthogonal point cloud images (Figure 6), 2D architectural drawings (floor plan, sections and facades) and a 3D model (LOD 400) was created (Figure 7). These surveyed elements contain exact geometry and position. [7] The section of point cloud shows the real undistorted section of the house and gives measurable...
Figure 7:
LOD 400 3D model

Figure 8:
3D surface model of the ornamented entrance
geometric and additional information without vector drawings. The 3D model and the orthogonal images are made for architectural visualization and to demonstrate the possible utilization of the many abandoned mansions in the country.

**Porta Speciosa**

Engineers of Mensor3D have digitalized and archived with a terrestrial laser scanner and structured light scanner the Porta Speciosa in Pannonhalma, Hungary. It is the more than thousand-year old Benedictine Abbey of Pannonhalma’s ornamented entrance, which is a part of the UNESCO world heritage site since 1996 and the first masterpiece of the Hungarian classic Gothic style. TLS was used to capture the cloister, while SLS was applied to survey the fine details, like ornamental leaves. The TLS and SLS did not get in direct contact with the artifact, the condition of the entrance was not damaged with the survey. The scanning and the collection of the data was followed by post-processing work and the derived 3D surface model can be used for reconstruction and interactive presentation as well (Figure 8). 3D models and the resulting reconstructions that present certain architectural periods help to build and verify hypotheses.

**Szombathely**

The 3D digital documentation of the complex system of the weaving factory’s halls took place in 2015. The factory’s more than 17,000 m² floor area was documented in 3 days. The inside and the facades of the building was scanned with terrestrial laser scanner, the non-passable flat roof was documented with unmanned aerial vehicle. The processed and registered point cloud was cut into separate parts and was exported in .e57 format. With this procedure an ArchiCAD compatible point cloud dataset was created, which was used by the architect one day after the survey. The ArchiCAD imports the point cloud and converts it into objects, which can be partly modified (display range, scale) and serves as a basis for the architectural planning and visualization. The point cloud and the 3D ArchiCAD model was used to visualize the possibilities of the factory’s reconstruction to the decision-makers one week after the survey.

**CONCLUSION**

These work projects are presented here to show how the advanced 3D technologies based survey system can produce more complex, valuable 3D dataset for architects and engineers. The combination of these technologies (TLS, SLS, UAV) provides better geometric data, realistic colored texture information and the places with lack of data can be minimalized. The number of the derived final products (architectural and engineering documentation, archaeological support, BIM model, visualization, etc.) are multiplying without increasing the on-site measuring time.

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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, 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."