1ST INTERNATIONAL ACADEMIC CONFERENCE

PLACES AND TECHNOLOGIES 2014

BELGRADE, 3-4. APRIL 2014 | KEEPING UP WITH TECHNOLOGIES TO IMPROVE PLACES

EDITORS:
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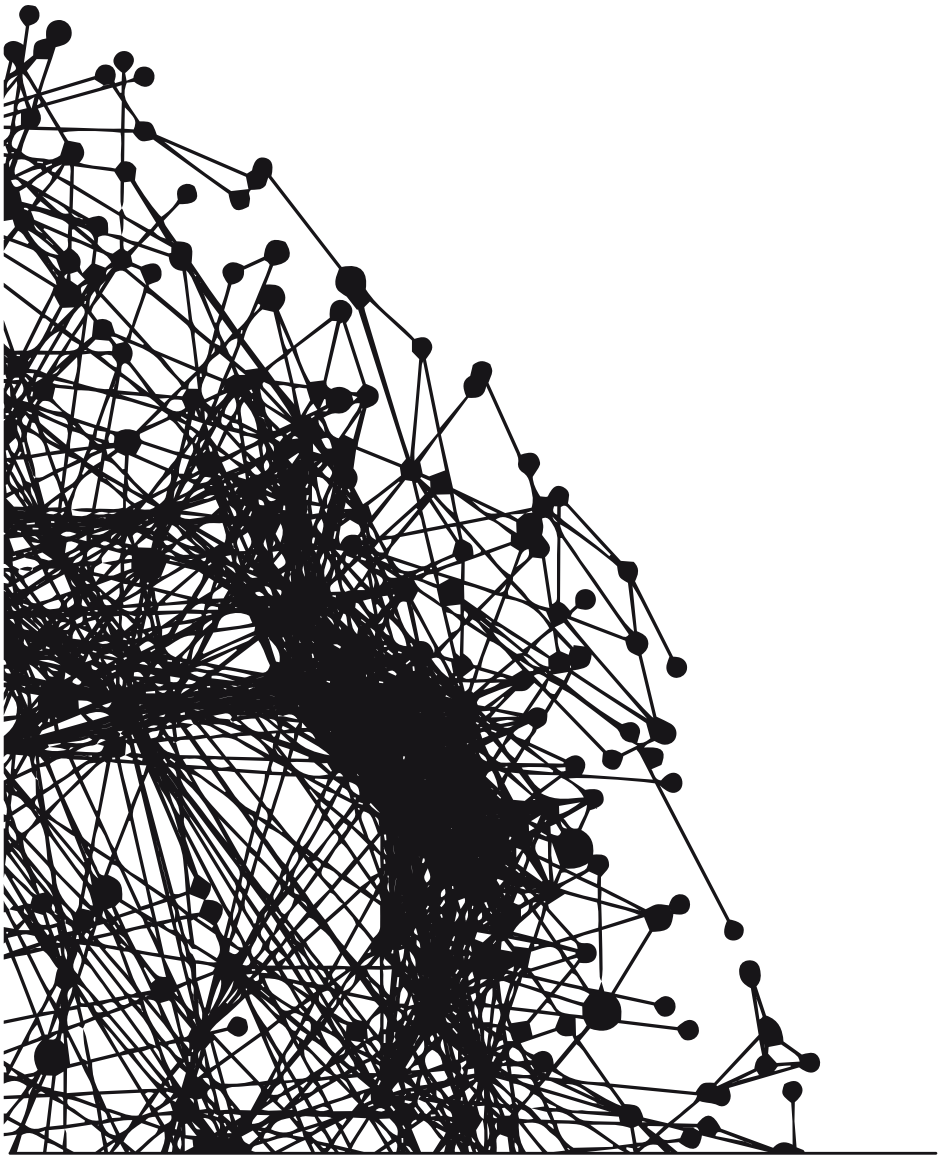
Aleksandra Krstić - Furundžić, Milena Vukmirović

conference proceedings



ISBN 978-86-7924-114-6

www.placesandtechnologies.eu

Proceedings of INTERNATIONAL ACADEMIC CONFERENCE ON PLACES AND TECHNOLOGIES

April 3-4, 2014, Belgrade, Serbia

PLACES AND TECHNOLOGIES 2014

Proceedings of First International Academic Conference on Places and Technologies

International Academic Conference on Places and Technologies, Places and Technologies 2014, will be the first conference organized by Univerisity of Belgrade – Faculty of Architecture, Professional association Urban Laboratory and University of Belgrade – Faculty of Philosophy.

Editors: Dr Eva Vaništa Lazarević, Dr Aleksandra Krstić-Furundžić, Dr Aleksandra Đukić and Dr Milena Vukmirović

For publisher: Dr Vladan Đokić

Publisher: University of Belgrade – Faculty of Architecture

Design: Stanislav Mirković

Place and year: Belgrade 2014

ISBN 978-86-7924-114-6

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

711.4.01(082)(0.034.2)
711.4:005.591.6(082)(0.034.2)

INTERNATIONAL Academic Conference on Places and Technologies (1st ; 2014 ; Belgrade)
Places and Technologies 2014 [Elektronski izvori] : keeping up with technologies to improve places : conference proceedings : 1st international academic conference, Belgrade, 3-4. April 2014 / [organized by Univerisity of Belgrade - Faculty of Architecture, Professional Association Urban Laboratory and University of Belgrade - Faculty of Philosophy] ; editors Eva Vaništa Lazarević ... [et al.]. - Belgrade : Faculty of Architecture, 2014 (Belgrade : Faculty of Architecture). - 1 USB fleš memorija ; 1 x 2 x 14 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovnog ekrana. - Tiraž 150. -
Bibliografija uz svaki rad.

ISBN 978-86-7924-114-6

1. Vaništa Lazarević, Eva, 1961- [уредник]
2. Faculty of Architecture (Belgrade)
a) Градови - Мултидисциплинарни приступ - Зборници b) Урбанистичко планирање - Технолошки развој - Зборници

COBISS.SR-ID 206380812

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TOWARDS GENERATIVE CONVERGENCE IN DESIGN OF ARCHITECTURAL STRUCTURES

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Abstract

This paper reviews theme of generative convergence and its implications on the relation between architecture and its production tools. Beside assimilation of digital technologies, assigning of knowledge and appropriation of methods processes and procedures of other disciplines also demarcate current architectural discourse. Transfer of technologies, whereas technology does not infer just hardware but a mode of system thinking, involves effort for their integration in a manner that should correspond specific needs and conditions of architectural practice. The transposition of creative tools influences re-thinking of design process in the course of the logic of operation of applied tool enabling innovation and categorical transformations.

Focused on design of architectural structures an approach for performance-oriented design generation will be presented. Concept of design process as a production system enables application of different strategies, integration and convergence of diverse production systems in a single meta-system. In order to operate in productive way, these methods use CAD/CAM/CAE cross-platform and connect an object with the set created by automated generative system, moving emphasis form a single object to a system and its possibilities to produce variations. Goals of such considerations are efficient use of resources and optimization of design process.

Keywords: Performance-Oriented Design, Integrated Design, Generative Convergence, CAD/CAM/CAE, Architectural Structures.

Introduction - Convergent Design Environments

The philosophy of integration is currently practiced in different domains. In an attempt to stay concurrent with fields of culture and production, architecture follows

that practice, competing their advanced environments by adapting new paradigms and performances. Assumption is that production tools, processes, mental and material creation would not fundamentally differ between diverse production categories. In addition, unification will represent a defining characteristic of the next generation of products and processes (Wroblewski, 2004). Faced with such reflections contemporary architectural theory and practice does not have a choice but to deal with the theme of generative convergence and its consequences.

Rapid evolution of technology and dramatic increases in complexity are changing the environment of architectural engineering. The challenges we face involve the convergence of design process driven by the proliferation of CAD/CAM/CAE cross-platform systems and automated production processes. These technologies enable experiments based on computational generation and digital fabrication of structures unconventional (i.e. non Euclidian) in its form, typology, and aesthetics, that were in past hard to conceive, represent, and produce. Innovation in structural forms are supported by the change in the creation process in which design, analysis, presentation, and production become part of collaborative process dependent exclusively upon digital technologies appointed by Kolarevic (2005) as *digital continuum*.

With the increase of computational capabilities, projects are converging toward a unique environment in which architecture and many types of knowledge-based expertise continuously crossover, exchange, analyze and produce information of all kinds. The expression of this condition is exemplified by the transformation of design studio into a design laboratory where designers experiment by acquiring terms and practicing discourses often borrowed from other disciplines, thus uniting art and science, mediating engineering and aesthetics. As the strict boundaries of design practice are increasingly questioned, broadened, and blurred, technology development and application, as well as incorporation of overlapping patterns, emerge as an essential vehicles for design exploration and assessment, opening possibilities for unanticipated outcomes. With that respect this paper will review the position, relevancy, and sustainability of the concept of generative convergence in design of architectural structures, its consequences, and in its implications on relation between architecture and its production tools.

Generative Convergence Construct

Definition of convergence strongly varies from the context. While in technological context it could be defined as *tendency for different technological systems to evolve toward performing similar tasks* (Wikipedia, 2013), digital convergence can refer to *previously separate technologies that now share resources and interact with each other synergistically* (Wikipedia, 2014). The design industry is continually searching for a new ways to break down barriers and develop improved methods to build products. According to Wroblewski (2004) convergent design represents *methodology for optimizing the intersections between products, processes and content*. Though architecture could not easily model on the consumers industry that

unites design and production in one company (Stratil, 2010), advanced digital technologies as alluded by Kolarevic (2005) enabled re-emergence of the contemporary master-builders ... *fully involved in the making of a building, where making of a building means design, production and construction in an almost medieval fashion*.

Convergence culture - a flow of content across multiple media platforms and the cooperation between multiple media industries (Jenkins, 2006.), has affected the way we interact with news and information. *Mediamorphosis* (Fidler, 1997), or convergence of digital media, enabled by rise of digital communication in the late 20th century, resulted in current state in which we are surrounded by a multi-level convergent media world where all models of communication and information are continually reforming to adapt to the enduring demands of technologies *changing the way we create, consume, learn and interact with each other* (Fidler, 1997). Convergence in this instance is realized by interlinking of computing and other information technologies, media content and communication network that has arisen as the result of the evolution and popularization of the Internet as well as the activities, products and services that have emerged in the digital media space.

The integration of social movement in cyberspace and participatory culture could be detected in architectural design through groups like open source architecture, open source programming and openly-shared computation. Technology cluster represent another example of integration (i.e. cluster of 3D technologies that connects - 3D digitalization/scanning, measurement, shape, dimension and deformation control, 3D computational technologies, 3D fabrication technologies). This approaches are not standard for architectural practice and by determination to implement them, we change design process by applying tools which are slightly inappropriate, considering that initially they were not designated for the process of conventional architectural design. Transposition of creative tool effects re-thinking of design process through the logic of operation of new tool, enabling innovation and categorical transformations. Because it could be practiced in all disciplines, it could be said that there are no *convergence designers* (Wroblewski, 2004). Architectural designrs who learn to program, marketing teams that employ anthropologists, and computer scientists who create music practice convergence design, by learning how through cross-disciplinary studies, diverse roles, and continual interest in the unknown.

In design of architectural structures generative convergence represents collaborative platform which efficiency is demonstrated through an integral multidisciplinary and performatively rational approach. While integration and multidisciplinary are being partly triggered by the specific character of the design field, performability, in this instance, is related to the inclusion of the structural performance consideration in the phase of design conception. Contrary to post-design optimization, application of generative from-finding techniques (i.e. qualitative and quantitative simulation and modelling), from the design outset, enables design exploration and evaluation, and facilitates rational performance based design concepts.

The challenge of convergence requires that we address complex designs in a new way, by embracing an idea of design chain that removes walls between design, analysis, construction. Convergence requires that we break down barriers between designer and generative design tools, between diverse medias for design communication, and between concept and its materialization. Theoretically, these obstacles could be overcome by using traditional methods. But those methods are prohibitively slow in the context of complex freeform structural design. In the future it will be virtually impossible to design highly integrated structures without removing the barriers within and in-between three identified domains, on the levels of - conception, communication, and construction. Within these three domain, we now confront three major areas of convergence.

Computer – Human/Designer Convergence

Development of information theories and related technologies, and accomplishments in the fields of Artificial intelligence and Cybernetics found its interpretation in design of architectural systems. Despite attempts to define autonomous design machines (Stiny and March, 1981) computational design relies on computer-human interaction for managing and implementing design generation. Application of computing technology in information processing is modus operandi following well-defined model expressed as an algorithm, or a protocol. Similarly, generative design represents productive, problem-solving discipline concentrated on a process flow defined by a recipe or a set of generative rules. The generative design arises in an algorithmic manner. The flow is based on self-organization and other predetermined autonomous processes. The instruction, or the program is defined by specified pattern (i.e. natural language, musical language, computer code, a mechanism, given composition). The generative process flows within the boundary conditions that can control but not determine the result (Stratil, 2010). Implications are architectural objects with the form that is no longer perceived as a fixed entity but a reactive system.

Generative design focuses on different methods that can simulate or interpret natural processes. Living nature has developed a specific method of synthesis controlled but not determined by physical information code of DNA and biochemical processes. The diversity and adaptability of organisms demonstrate the potential of these techniques to handle complex problems in design and to generate novelty and diversity from simple units (Stratil, 2010). In the context of the design of architectural structures derivation of optimal forms is realized by different evolutionary computational strategies (i.e. Evolutionary Algorithms, Genetic Algorithms, Evolutionary Topology Optimization, etc.) that have been merged into a research field labelled as computational morphogenesis. These techniques extend potentials of traditional form-finding tools implying possibly their new purposes within design process (Milošević, 2013).

Interface design that relies on computer-human interaction uses generative methods that offer a promising way of conceptualizing and working within a given context. Since they are implemented through an algorithm, the question arises

whether such processes still represent design. In traditional design the relationship between the designer and the object is commonly a direct one. Contrastingly, design by using generative methods arises autonomously. In this set, digital media applied for from production gain critical generative capacity, exceeding initial role of tool, in terms that they actively participate in creation and to some extent shape designers process of reflection. Furthermore, the definition and implementation of new, experimental, high-reliable, precise and efficient tools and application that accelerate design production represents an integral part of such design processes. Moreover, this kind of researches are not only restricted to the advanced use of commercial software but also to the development of customized subroutines and functions, transforming designer from software user into software developer and intensifying computer-human interaction.

Digital – Analog Convergence

Communication of the design ideas rarely relies on a single type of representation but rather on a network of geometric and non-geometric, digital and analog descriptions. In order to explore, evaluate and communicate their ideas practitioners in the field of design of architectural structures used diverse simulation and modelling techniques, from physical models (i.e. funicular models, soap film models, etc.), to virtual modelling techniques, since the 1970s (Dynamic Relaxation, Force Density Method, Finite Element Analysis). Technologies for structural performance based design have undergone a major transformation, from essentially static to interactive. Permanent progress of digital technologies (CAD/CAM/CEA, CNC, Rapid Prototyping, Optical measuring, Reverse Engineering, VR/AR), particularly from the middle of 1990s, opens up new opportunities for their use in the contexts of research and practice in the field of architectural engineering.

Production of form through the process of performance analysis and evaluations represents standard approach in the field of engineering but it is still not enough exploited in the field of architecture. Integration of design and structural analysis, that has remained an elusive goal due to mashing and data model transition that introduce discrepancies between design and analysis models thus breaking the design-analysis cycle, now can be grasp by Isogemetric approach (Hughes, 2005). By providing consistency between design and analysis models, this approach facilitates repeated analysis of parametric and free-form changes in geometry, shape and topology optimization, as well as effortless and simultaneous studies. Additionally, CAD/CAM and diverse rapid prototyping technologies offer different possibilities for fast production of 3D physical models (prototypes) in terms of accuracy, materialization quality and rate of development. These convergent growing techniques are used for production of models that could be used for aesthetical, spatial and structural evaluations, in all kind of functional tests that are sometimes required step preceding digital fabrication of real scale structure.

Material – Immaterial Convergence

Through the history of architecture necessity for efficiency was placed in-between dichotomies material/physical and immaterial/moral, expressed by Vitruvius trinity -

solidity (*firmitas*), utility (*utilitas*), beauty (*venustas*). Though architecture represents the connection between the shaping of material (*fabrica*) and rational conclusion (*ratiocination*), inconsistency in production process in the point of transition of design idea (immaterial) into a designed object (material) is identified as one of the key issues in complex freeform design. Constant development of digital fabrication techniques towards integration of material and immaterial aspect of architecture is increasingly liberating design process of restrictions imposed by construction demands.

Three dimensional computer models enabled formal exploration and analysis of digitally generated complex geometries and their dynamic transformations, in the way that was almost unimaginable before use of computers. Relation between phase of conception and production is redefines by establishing of direct link, introducing *file-to-factory* procedures and CNC production technologies. Realization of formally complex design solutions became less the question of feasibility, and more in the function of its computer generation and new tools necessary for digital production.

With the advent of rapid prototyping techniques (e.g. Dimitrov, 2006), it is now possible to fabricate complicated topologies directly from computer models using 3D printers to reproduce structural details point-by-point and layer-by-layer. Technique similar to 3D printing, referred as Counter Crafting, is being developed for the automated construction of whole buildings (Khoshnevis, 2004). This or similar type of fabrication techniques could be used in the future to construct unconventional architectural designs involving complex geometries generated by discussed design techniques.

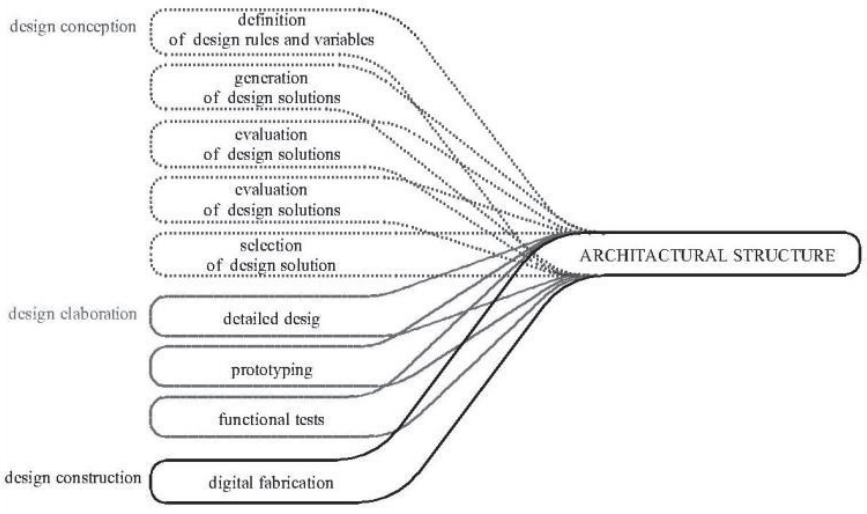

Figure 45: convergent generative design process

Conclusions

Design process is based on two-directional relation between designer and production tools. Assimilation of information technologies considerably changed that relation, opening opportunity for design exploration based on discovered potentials of computational tools. Transition of design process in automotive, simulative and interactive computational environments allowed widening of the potential architectural forms that should be leveraged to respond challenges posed by performance and aesthetics to create new formal and structural possibilities. This delocalization of the design activity across multi-dimensional grids of knowledge calls for a projective methods that would assure the assessment of its critical value, the nature of its performance, production and experiments.

Projects that embody convergence design principles blaze horizontal paths through organizations and build combinations and interactions of information. Because these projects span multiple disciplines, they rely on core design principles that are common to many fields of study. Designers are increasingly looking for cooperation to provide integrated solutions that will break down convergence barriers. Remarkable structures that advantage of design convergence are realized by production of the tools that designers need, tools that easily integrate with one another through the design chain and tackle convergence issue.

Acknowledgement

Authors are supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, Project No TR36008.

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