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REDEFINITION OF THE PROCESS OF DESIGN AND REALIZATION IN EMERGING ARCHITECTURE ON THE PRINCIPLE OF "DIGITAL CHAIN"

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Abstract. *The setting of design and architectural realization today cannot be considered separately from the emerging architecture, which is based on digital technology. Digital technology has primarily affected the architectural presentation, and eventually began to represent a design tool directly connected with the realization, which was across various digital techniques establishing continuity of a „digital gap" as a global problem of discontinuity of design and realization in architecture and fulfilling complex design requirements of the architecture today. With the characteristics of continuous connection, this relation design - realization is increasingly manifested as a CAAD/CAM technology and the most commonly researched as a „digital chain" principle. Primarily, the term „digital chain" is defined and investigated (theoretically, experimentally and practically) at the CAAD department at ETH Zurich (germ. ETH Zuerich) within the research projects of this institute. Today the tool has become an indispensable, inevitable and active, and the architect seemingly passive and in an unclear position in the whole process and the offered solutions of space and architecture. Accordingly, the paper explains the principle of "digital chain", and overlapping with elements of a conventional (standard) architectural approach, based on the settings of the positioning architects in new conditions, redefines the process of design and realization in the emerging architecture in architectonic sense.*

Key words: *emerging architecture, redefinition of architectural process, CAD/CAM, "digital chain", positioning of architect*

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1. INTRODUCTION

Digital technology in recent two decades is significantly pushing the boundaries of design process and realization of architecture. Complex requirements and conditions create a perfect environment for the effective use of tools. However, the development of digital technology does not follow the needs of the architectural product, although they exist in parallel.

Digital CAAD/CAM technology[4] is already largely represented in the architecture worldwide. Whole or in part, the leading world architects[5] are using it in various aspects of their work.

Digital technology is a tool, which allows translation of ideas into reality by approaches including the manufacturing part into conceptual part of the architectural process. By mutual intertwining between architecture and technology, today architecture expands and changes the interdisciplinary fields of its activities, so it can work harder decoupled from other disciplines. Current architecture has not been determined, nor focused, initially technologically based and it is named as emerging architecture.

The connection between architecture and digital technology exist, but the technology today unreasonably assumes, in certain segments, the primary role related to the architectural idea. This paper consider subject as architectonic approach and not as instructions for choosing tools and techniques in process of design and realization.

2. CONTEXT AND COMPLEXITY OF THE PROCESS OF DESIGN AND REALIZATION IN EMERGING ARCHITECTURE WITH EXPLANATION OF THE "DIGITAL CHAIN" PRINCIPLE

The relationship of architecture and digital technologies is, generally speaking, developing from the first generation of computer aided (CAD) system, which offered only limited computer visualization software and documentation focused on a two-dimensional representation of three-dimensional objects and which is used only in the preliminary stages of design, analog to drawing, as the main architectural meaning of communication and transmission of ideas. Later developed systems were given the ability for design of complex model geometry with approach to 3D geometric modeling and possible structural and dimensional analysis thereof; and exported encoded design requirement into the finalized architectural product connected to computer numerically controlled (CNC) machines. Today, computer aided architectural design (CAAD), with computer-aided manufacturing (CAM), is mainly the medium, which collects and organizes the necessary

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[4] INDEX OF SIGNS, SHORTCUTS AND SYMBOLS

CAD Computer Aided Design
CAAD Computer Aided Architectural Design
ETHZ ger. Die Eidgenössische Technische Hochschule Zürich
CNC Computer Numerical Control
CAM Computer aided manufacturing
3D three-dimensional
Interface distributed environment in which two components of a computer system exchange the information
Mass customization mass production with limited series by specific customer requirements

[5] Herzog&de Meuron, UN Studio Amsterdam, Frank O. Gehry, PTW Architects, Renzo Piano, Nicholas Grimshaw, Future Systems, Norman Foster, Coophimmelb(l)au, Massiiliano Fuksas, MVRDV, OMA, Diller&Scofidio, Toyo Ito...

information and through code sends a message about a particular process of design and realization of architecture by communication and simulation of technology.

Architecture now inevitably must provide effective solutions of a wide range of complex issues and requirements, which are included in its interdisciplinary nature and for which there have been developed technological tools, but not properly used. The assumption is that the only way to achieve meaningful and seamless management of these conditions and messages system is if it is done by architects. Digital design represents the transformation of traditional design activity by introducing the entire combined group of structural engineering technologies, new materials, manufacturing and construction processes that computer discovers, permits, conditions and supports at the beginning; while later with a large number of experimental processes and products, the whole process has become also reversible.

Emerging architecture is current architectural reality represented by a wide range of different types of architectural products created in parallel processes of design and realization by conventional, digital or combined tools. In response to a complex context and requirements of emerging architecture itself, with experimental mode based on the digital approach with constant trials, changes and required passing the prototype phase, it is in most cases also the testing of complete process of design and fabrication - production, materials and the machine.

Conditionality of new approaches is based on the technological meaning of interactive design and realization of architecture that requires, in the sociological meaning, the interactivity of subjects – participants in the architectural process within the idea, external and internal influences, modeling and implementation of a prototype to the final product - the architecture. The core objective of the architecture remains the same, but the process and the roles of participant change significantly.

Emerging architecture context is itself complex, composed of several layers of different networking disciplines. In contemporary terms, the architecture is closely related to urban planning and correlated to the art and construction. Within architecture this research covers a variety of scientific fields and includes, among other topics philosophy of technology, theory of design, digital fabrication, geometry, mathematics, mechanical and electro technical engineering, socio-cultural and cognitive science, which all together lead to interdisciplinarity of the topic.

The term of context in a digital way of thinking has a completely new meaning. We now create the context for the code of an artificial environment, where the selected parameters have the role of factors that influence and define the digital design (Markovic, 2009). Now, this is the environment of digital design, i.e. coding.

The principle of the design process and realization of the architecture, most commonly used to cope with a large number of variable parameters of architectural products and/or the context in which it exists is the "digital chain". This is the way of representing the multifunctional character of micro and macro spaces in the form of assumed changes as the coding parameters and/or user requirements. Complexity, as the rationale for use, is not always related to the complexity of the forms, but also to complexity of the complete concept, appearance or construction of the building, as well as the complexity of relationships, which are the fundamentals of the process (Markovic, 2013).

The *"digital chain"* is a metaphor for the digital design process made from design assignment, through the approach to the design assignment and design to its production in

architecture, which is supported in every step by a computer. Prof. Dr. Ludger Hovestadt from CAAD Chair[6] at the ETH Zurich described this process as: *"The CAAD Chair (Computer aided architectural Design) under the leading rule of Prof. Hovestadt at the ETHZ developed in the last four years prototypes of "Digital Chain of Production". The aim of this work is to show the process of design and building, which is in every step supported by computers and whose interfaces are digital. A "Digital Chain" is an uninterruptible digital process from the design (structure and form finding), over the construction (detail) to production (CNC- fabrication (manufacture)). Every step is programmed entity, which are connected by universal interfaces. The computer does not appear like a passive digital drawing board, but like an active design controlled work tool. Rules, connections and aims are verbalized by architects, who can make optimizations of a number of different variants as a result of computing power of computer. The role of architects moves from designer of form to designer of process. The Aesthetic of results is sometimes exciting and exceptional, sometimes organic and self-evident… it is always result of specified parameters.*
There are crystallized three topics, which could have influence to contemporary architecture: efficiency, complexity and refinement. "

The beginning of the ″digital chain″ gives input to the whole digital design process as design assignment.

The demystification of the ″digital chain″ (Markovic, 2013) is done by explaining the components of this process, their overlapping or discrepancies in relation to the conventional design and realization in architecture, as well as their manifestation through the practical use in architecture.

The whole digital process is explained by a chain of links, which are organized in different ways and represents organized sub-process in the ″digital chain″ (Fig. 1). The *links* are:

1. Approach to design assignment
2. Digital design - coding
3. Production 1 - prototype
4. Production 2 - production of structure

They occur individually and as a part of the chain under influence of a number of *connectors*. The connectors are based on the interactivity of complex design process and realization in architecture and represent disruptions in the chain's linearity:

a. Internal and external influences to the approach to design assignment and to digital design - coding
b. Influences of machine and material parameter
c. Fabrication - influence of transport tools and assembling

The end of the chain is related to the post-production period and is linked to the presentation, and confirmation of structures.

[6] http://www.caad.arch.ethz.ch/blog

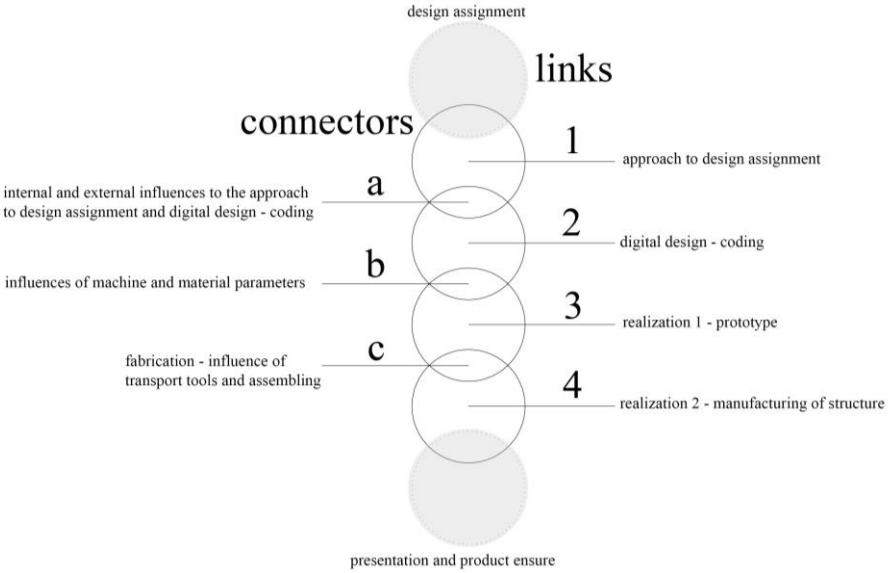

Fig. 1 "Digital chain" – scheme with elements of the "digital chain" *links* and *connectors*

The components of the ″digital chain″ are determined and clarified by collected facts in catalog of the referenced starting points in researched publication cards, buildings, and scientific work in institutes and in this way found their own place in different place of research (theory, design and production) (Markovic, 2009).

"Digital chain" practices integration between information technology and architecture through theoretical research of the effectiveness of the digital tools impact in process of design and production in architecture; alters technical thinking in architecture in relation to information technology and opportunities in relation to the design and acceptance of architecture driven by a computer as a medium.

"Digital chain" in architecture is set as a principle of connected design and realization through coding in terms of the complexity of parallel codes into the completed product.

Concerning the *network intelligence* and reintegration of architect into production and the way of approach to principle of the "digital chain", "we might began by noting that *design* is both a noun and a verb and can refer either to the end product or the process" (Lawson, 2004) , as well as that till now "design has been described as making inspired decisions with incomplete information" (Aish, 2005).

Building systems have been developed, which consist of the components that are related to a CNC machine by parameters. Computers are used for data processing in the design process, and then in a translation of design directly from CAD to CNC production machines, what means that the computer brings architectonics value of the final product. In this way, the formulation of the problem itself becomes a form of problem solving (Svetel, 2002).

3. OVERLAPPING OF CONVENTIONAL AND "DIGITAL CHAIN" PRINCIPLES IN THE PROCESS OF DESIGN AND REALIZATION IN ARCHITECTURE

Digital phenomenology as a driver of idea of digitalization in architecture is not only an organized process, but also an effective way of solving standard architectural problems with a long path and separation from design to realization. Emerging architecture sets in front of architects a large number of requests, which are now in addition to standard also digital, mutually conditioned with more or less acceptable varying results. The principle of "digital chain" outperforms the *digital gap*. Digital and conventional vocabulary, the equally named characteristics and activity of architecture receive new meanings.

The development and behavior of the architectural process through the impact of digital technology, as well as the theoretical and practical research of technology of computer numerical control (CNC) in architectural terms, is best considered by overlapping with conventional experience in design and realization (Lawson, 2004, 2005, 2009) for determining basic intersections.

As it has been previously mentioned, the first intersection is the architectural context. It is, basically, the connection of thoughts and different levels of communication. Urban and environmental conditions include communication of architecture with regulatory norms, standards and planning solutions, more represented on the global level of the system. Previously, context included communication with the environment and the neighbor, i.e. *genius loci*. Today, context means communication with the present situation also in terms of technological advancement. Further speaking, the new context is communication of the programming parameters, i.e. coding. Emerging architecture is also a product of overlapping of technological tools and context with itself, connections to different complex requirements, approaches and action by the expert who has the skills of a meaningful connection to the product, i.e. space. The architect is a creator of the code for product creation. Compliance of architecture with the functional requirements, as well as the standards of design and dimensions corresponding to the user. On the other hand, the economic unsustainability of a single function and complex activities of a human introduce as the basic requirement the multi-functionality, i.e. flexibility of space. It is particularly reflected in the utility parameter of major projects with prediction and discussion of the different functional programs aimed as sustainability of architecture. Design is the process of harmonization of context and functions as a 3D geometric results - form, passing all aesthetic criteria guided by the architect (Fig. 2).

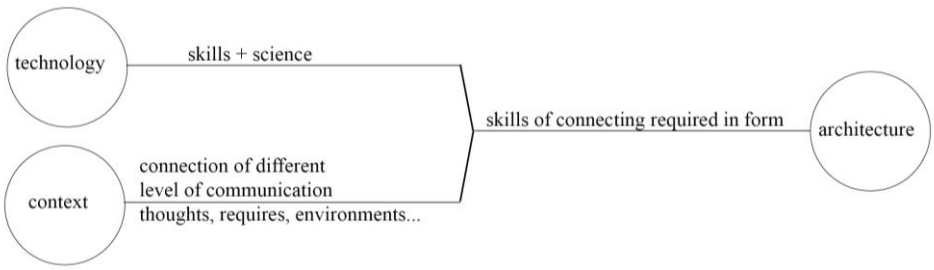

Fig. 2 Relationship of complexity of emerging architecture requirements

The conventional approach to the design and realization of the architecture is based on a preliminary design of the design task, as overviewed through the personal vision of the architect.

By Richard Maccormac (Lawson, Doorst, 2009)[7], the design process is a *journey*. The same statement today is related to the developing process of creating the architecture that is re-reviewed and redefined. By defining the architectural process from different points of view, we are led to constantly come up with some kind of chain in architecture, whether we are talking about a conventional or a digital approach. The chain in architecture always consists of determinate links and connections, whose determination under the influence of demands and opportunities, by time, changes and re-constitutes.

Conventional architectural process is a chain process that basically consists of design parts and manufacturing architecture based on the methodology, trust, knowledge and experience of the architect. Architectural chain is essentially made up of ideas, projects, models, development and realization in single collaborative circles and common line (Fig. 3).

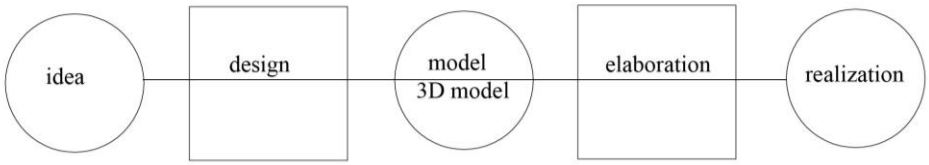

Fig. 3 The conventional procedural model in design and realization in emerging architecture

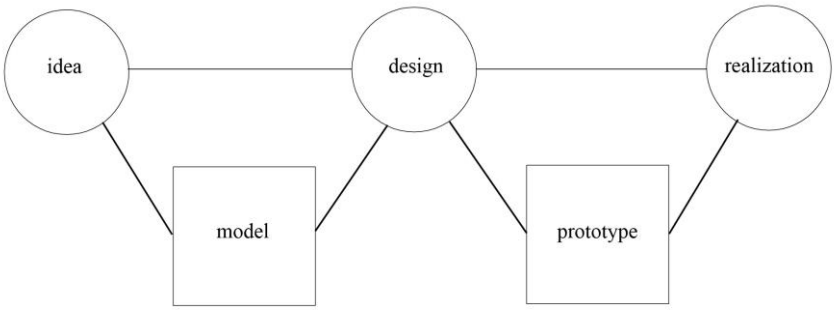

Fig. 4 The digital procedural model in design and realization in emerging architecture

Structure of the chain has changed in time and is changing now by introduction of more complex tools. Digital architectural process is an upgraded version of the conventional chain in architecture (Fig. 4). Computational tools are there to develop design solutions for complex requirements, but in parallel, create also some architectural limitations. The progress of technology and strengthening related to the architecture is today set in front of us and requires analysis of the current position and positioning of architects in new circumstances.

[7] Richard Maccormac: *The design process is a journey, an episodic journey towards a destination which you don't know about, which is what life is and what writing and all arts are like, a journey.*

Previously mentioned necessary effective solutions of complex context, issue and architectural nature coded through developed technological tools, can be achieved by only one medium - the architect. The connection, role and intention of the architect to the design and realization of architecture are inseparable and that relationship is timeless and mutually dependent. Position of architects is only variable depending on the development of tools design and implementation.

By analysis of the standard design and realization we come to the key positions of architects and by overlapping them with parts of the "digital chain", we get the necessary activities and characteristics of architects in the new approach. The lack of architects in the process becomes a question of compromising the continuity of the process of "digital chain". Architectural activities are essentially based on the areas of education, the practice of architecture and linking theory with practice of architecture and vice versa. Architect maintains a continuity of digital approach elements - as fluid in the relationship human - machine - material. Creation and development of design expertise are the qualities of each designer and a core thread of each architectural process. Architect more than ever has to go back to his *Vitruvian* roots and to be combination of theoretician alienated from the present and life, the artist open to technological developments and engineer integrated with other disciplines on the one hand and on the other, with nature.

This expertise is summarized in a seemingly small but huge part of the project - in the idea. The idea is always associated with intuition and a sense of architects and represents a bridge between the problems and the solutions. Although it is never a specific product, for the architect it is. Seeing in this moment is seeing also at the very end. Specifically, it binds to the standard thinking through drawings, which, as Denise Scott Brown says, *are never done as a piece of art, they are done as communication with self* and with people around the table (Lawson, Doorst, 2009). Ideas for architects always need further improvement, review and reinterpretation.

The basis of the standard design is the drawing, which is connected with the realization and working in parallel and above mentioned – communication. In the past, when there were no drawings or the projects, the point was only in the making. Drawing is also an instrument, check, a system of symbols, transformation between problems and solutions (Lawson, 2005). Drawing is a presentation of imagination and idea, analysis and confirmation of the idea, as for Carlo Scarpa, who said that *he wants to see and that just because he draws*.

The line of digital architectural process provides an ideal balance of architectural continuous process, which by coding as procedure from idea through prototype to realization, enables creativity and control simultaneously. (Fig. 5) The code allows different levels of communication in design. It is at the same time: the line, the model and the prototype, as well as the concept, detailed design and architecture.

By Lawson and Doorst (2005) the more true graphic of design process can be seen as triangle: analysis – evaluation – synthesis. In parallel with digital approach, it is again a chain with connections to different influences, primarily, mixture of creativity and analysis. Digital design starts with a learning - a proposal considered through experiment. Then an evolution phase comes - a creative leap, transformation of problems to solutions in the form of intermediate solution, that is neither fixed nor completely free. Synthesis comes as coherent integration of the content - the answer to many questions in one integrated solution. The design process as a basic human activity is a special way of thinking. Unlike

the artist, the designer's freedom is always limited by specific requests and the creation process is based on the experiment (testing and learning on a given proposal through the design).

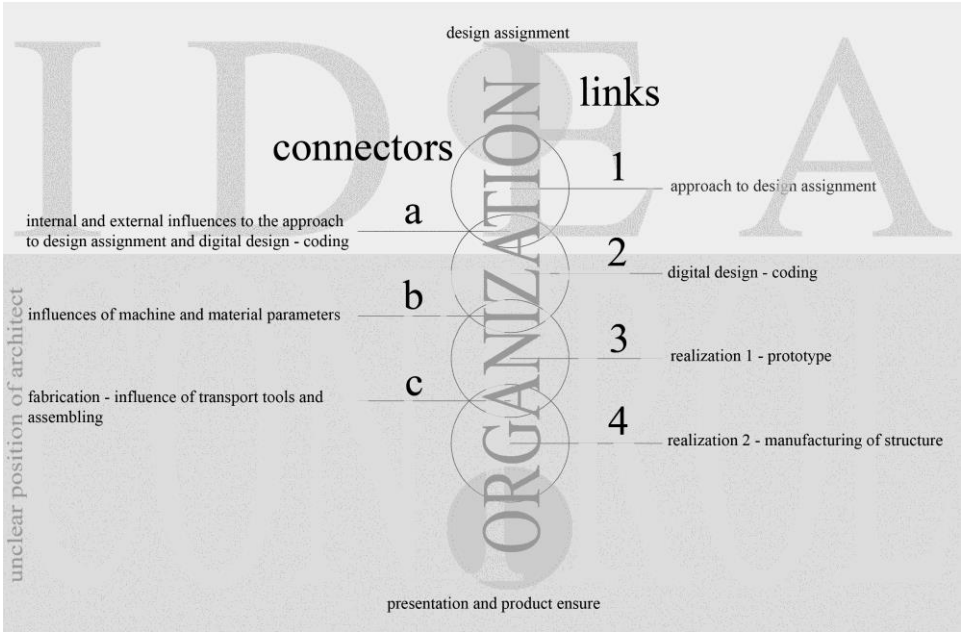

Fig. 5 Positioning of three dominant characteristics of the architect in "digital chain"

The standard process line has a fault, as direct disconnection with the realization, so often a part of the developed project, remains bound to the site and changes the architecture.

On the other hand, the design and realization of a "digital chain" are not separated, but substantially overlapped, as the influences of machines are already included in the idea at the beginning and at the link 3 (realization 1 - prototype) (Fig. 6). The limitation of architects control in production is reduced. Parts of the conventional design are present throughout the chain with an indication that the machine is obtained directly at the idea (Fig. 7). The parts of idea and realization are much closer, through the design. The architect designs the process and returns to the realization indirectly – by knowing machine and materials parameters necessary for coding the idea and directly - in terms of products control. *The focus is on the idea that the designer introduces to the program and on the possibility of expressing those ideas by using the idea of the program development.* (Peters, 2013)

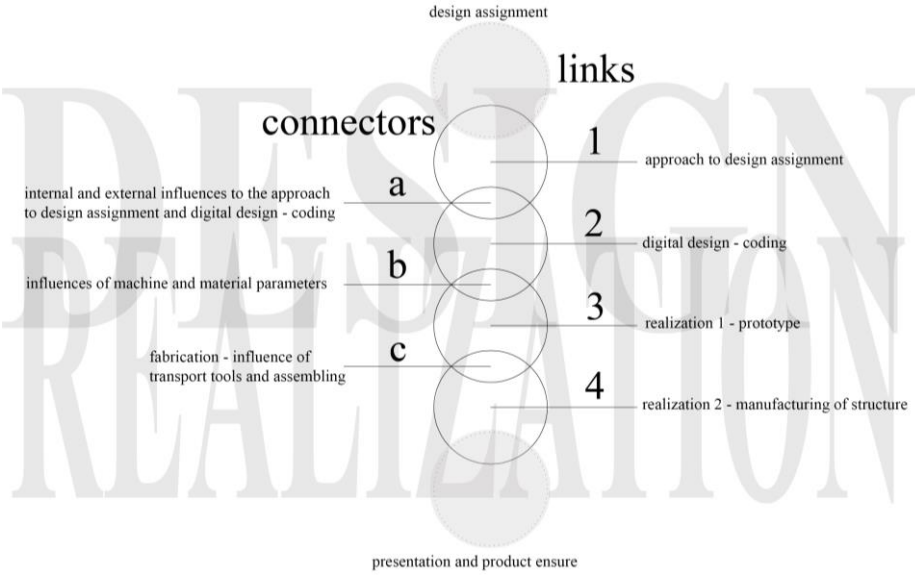

Fig. 6 The *connections* and *links* in standards process of architectural creation

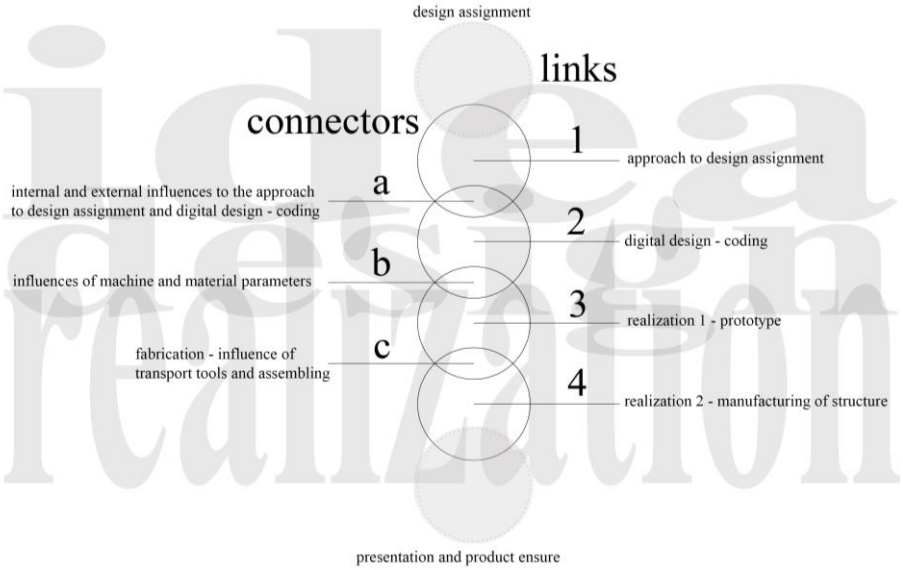

Fig. 7 "Digital chain" with parts of project design in standard chain in architecture

The necessity of thinking, critical opinion and logical activity by architects is obvious, but the positions of its necessity are not specified and defined. In the new process, the architect's position is interactive in every step of flexible control that, on one hand, allows creativity while on the other amplifies ambiguity of architect's position. *The purpose of the controller is to manage information by translating and converting one binary language*

to another so that language understood easily by humans may be easily understood by machines tool specific to each tool (Schodek, 2005).The essence of this process is also directly driven by architect, who controls the design in terms of realization of creative and controlled solutions and production by knowing and creating new tools. Architects *will design the behavior and responsiveness of the machine itself* (Kohler, 2014).

The topic is based on studying current state, but directly related to the current limited presence of architects in the digital design, based on a process of "digital chain" as a solution of the global problem of discontinuity of design and realization in architecture, i.e. “digital gap" as well as use of mass customization. By connecting the design process with defined areas of "digital chain", we not only obtain results that help in overcoming the disadvantages and prejudices about architectural digital tools but also create them. All that together is enhancing the benefits of their use in the design process with constant monitoring of architect.

5. CONCLUSION

This paper provides a new and special reference to the definition of the design process and realization in emerging architecture on the principle of the "digital chain" as a continuous process that is changing, monitoring and conditioning the development of architecture. The research is based on detailed studies of the characteristics of the process and the issues that arise in the context of the "digital chain" as its nonlinearity, explained and helped to understand them, to localize, solve and thus improve the process.

Redefinition of architectural and technological process of design and realization is carried out through the eyes of architects with the dualistic approach to the design and realization of architecture, by establishing the principle of positioning and role of architect now regarding comparison to conventional process and the development of a digital approach to architecture on the principle of the "digital chain".

Digital technology is including information and communications technologies so that new technology provides the transformation of society, settings of conditions for social change and progress, and therefore technological innovation is becoming a driver of the progress (Miller, 2011). Technology is the active agent that moves the culture and society after the causal principle. It always occurred independently of the society, but the society later must cope with new situations, that it causes. In the overall understanding of digital culture it is necessary to examine the changes and the formation of transformation and cultural forms of different processes - phenomena, which already presents a significant part of the user and media culture.

In regard to this transformation, architecturally speaking, positioning of architects in the design and realization of the architecture in the digital CAD/CAM approach is crucial for redefinition settings, but it is still current, flexible, and depends on the process and the relationship of architecture and technology. It is based on trust and certainty of architects in technological innovation and acceptance of digital culture as progress, in which the user is enabled the direct role in designing.

The directions of the new investigations are open in the scientific field of detailed studying of the architectural influence in the digital approach to architecture and the detailed positioning in terms of the activities and characteristics of architect’s role in the design and realization in architecture by the digital principles. Investigations are opened, as well, in the field of direct connection between digital design and realization in terms of

translating code from the design to the machine and the creation of new, and improvement of existing applications and production digital tools.

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REDEFINICIJA PROCESA PROJEKTOVANJA I RELIZACIJE ARHITEKTURE U NOVONASTAJUĆOJ ARHITEKTURI PO PRINCIPU "DIGITALNOG LANCA"

Postavka projektovanja i realizacije arhitekture danas se ne može posmatrati odvojeno od novonastajuće arhitekture (engl. emerging architecture), koja je bazirana na digitalnoj tehnologiji. Digitalna tehnologija je prvenstveno uticala na prezentaciju arhitekture, dok je vremenom počela da predstavlja i alat za projektovanje sa direktnom vezom sa realizacijom, koja je preko različitih digitalnih tehnika uspostavljala kontinuitet "digitalnog jaza" kao globalnog problema diskonuiteta izmedju projektovanja i realizacije arhitekture i ispunjavala kompleksne zahteve projektovanja danas. Sa karateristikama kontinualne veze, odnos projektovanje – realizacija se sve više manifestuje kao CAD/CAM tehnologija i često istražuje i kao princip "digitalnog lanca". Prvenstveno, termin "digitalni lanac" je definisan i istraživan (teoretski, eksperimentalno i praktično) na CAAD katedri na ETH Cirih (nem. ETH Zuerich) u okviru naučnih projekata ovog instituta. Danas je kao alat postao neophodan, neminovan i aktivan, a arhitekta naizgled pasivan i u nejasnoj poziciji u celom procesu i ponuđenom rešenju prostora i arhitekture. U skladu sa tim, rad objašnjava princip "digitalnog lanca", a preklapanjem sa elementima konvencionalnog arhitektonskog pristupa, bazirajući se na postavkama pozicioniranja arhitekte u novim uslovima, redefiniše proces projektovanja i realizacije novonastajuće arhitekture u smislu arhitektoničnosti.

Ključne reči: *novonastajuća arhitektura, redefinicija, CAD/CAM, "digitalni lanac", pozicioniranje, arhitekta*