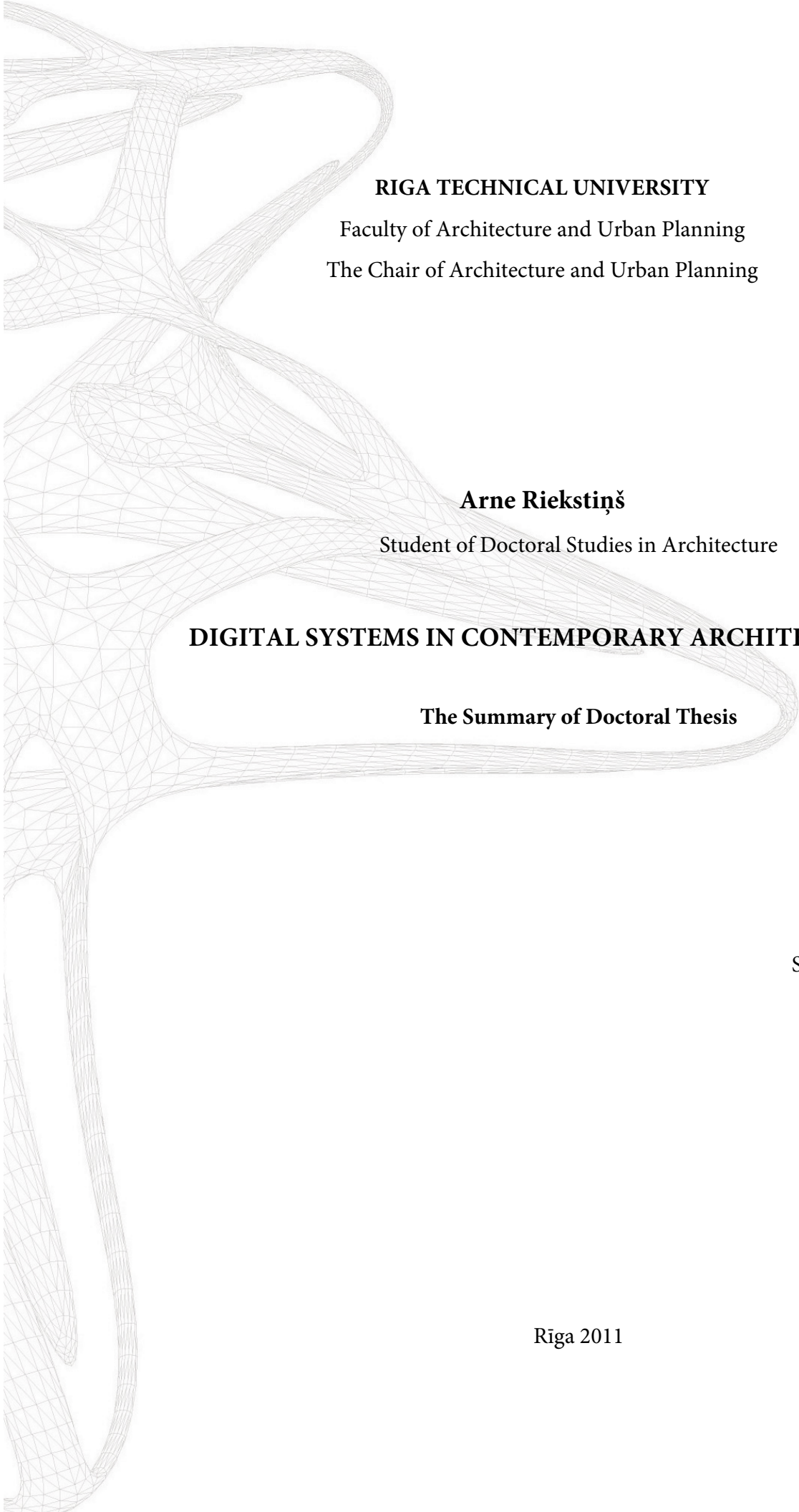




RIGA TECHNICAL UNIVERSITY

Faculty of Architecture and Urban Planning
The Chair of Architecture and Urban Planning

Arne Riekstiņš

Student of Doctoral Studies in Architecture

DIGITAL SYSTEMS IN CONTEMPORARY ARCHITECTURE

The Summary of Doctoral Thesis

Scientific Advisor

Dr. arch., Prof.

Jānis Briņķis

Rīga 2011

**THE DOCTORAL THESIS
HAS BEEN NOMINATED IN RIGA TECHNICAL UNIVERSITY
FOR OBTAINING A DOCTORAL DEGREE**

The doctoral thesis for obtaining a doctoral degree in architecture is being publicly defended on 16th of November 2011 at 10:00 in the Riga Technical University's Faculty of Architecture and Urban Planning, Āzenes iela 16, Rīga, room 406.

OFFICIAL REVIEWERS

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CONFIRMATION

I, Arne Riekstiņš, confirm that I have worked out this doctoral thesis that has been handed in for reviewing in Riga Technical University for obtaining a doctoral degree. This doctoral thesis has not been handed in to any other university for obtaining a scientific degree.

Arne Riekstiņš
21.06.2011.



THE OVERALL DESCRIPTION OF THE DOCTORAL THESIS

This thesis is composed of introduction, 3 parts with 12 chapters (2–6 each), conclusions and annexes. The contents of the thesis:

Introduction

1. Digital Architecture

- 1.1. History of Computer Aided Design and its usage nowadays
- 1.2. Theoretical Findings in Digital Architecture
- 1.3. Classical Design Tools of Digital Architecture
- 1.4. Innovative and Non-traditional Digital Systems Used in the Architectural Design
 - 1.4.1. Software
 - 1.4.2. Computer Aided Manufacturing Hardware

2. Role of Digital Systems in the Architect's Creative Process

- 2.1. Most Significant Architectural Projects Worldwide
- 2.2. Tendencies of Digital Systems in the Regional Context, the Examples of Latvia and the Baltics

3. Potential Usage Possibilities of Theoretical and Practical Findings in the Architectural Design

- 3.1. Designing of Genetic Architecture
- 3.2. Designing of Parametric Architecture
- 3.3. Designing of Evolutionary Computation
- 3.4. Topological Modeling in Architecture
- 3.5. Fluid Urbanism and the Architectural Animation
- 3.6. Algorithmic Architecture, Scripting and Generative Design Methods

Conclusions

Annexes

References

INTRODUCTION

Actuality of the Subject

In the world many realized solutions of the tendencies in contemporary architecture have been possible only thanks to digital design tools. The origins of Computer Aided Design systems are dating back to the sixties of 20th century and it is widely known as *CAD*. To make production more effective, faster and more precise, these tools were specially developed for the needs of military industries that alongside developed Computer Aided Manufacturing, also known as *CAM*. This relationship of design and manufacturing is also being called as the *CAD/CAM* paradigm. The specialized digital tools for architectural design started to be developed roughly 30 years ago. Originally they were based on the computer design tools derived from other industries. In the last twenty years time there has been a specialization in the field of architecture and currently many unique digital tools have been developed that have been borrowed from the industrial design, aviation, naval and other fields that have no direct references to architecture. Also many new hybrid architectural trends have been formed – biodigital architecture, genetic architecture, parametric architecture, evolutionary computation design, morphodynamics, biomimetics etc. (the origins and explanations of terms has been codified in the Annex No. 1 of this thesis). This vast mechanism of computer usage in architecture is a wide field of research. International symposiums and conferences are being held regularly that every time unite ever growing amount of those being interested in this area. The developers of new digital systems are organizing workshops and lecture courses that are widely being attended by the young generation of architects joined by architects with a significant work experience, for example, Norman Foster, Frank Gehry, Zaha Hadid, Toyo Ito. These tools are going into a wider range of usage with an ever-growing impact, becoming more affordable, and they can be used for facilitating the whole designing process and for designing with previously non-determined intuitive ways. That ensures design of formally and technically complex buildings meantime keeping track of and optimizing the building costs. Current insights on architectural design in the professional environment mostly is linked to the usage of one or another computer software tool. But designing of thoroughly complete architecture demands a wider approach and a synthetic view. One of the most actual factors that can ensure higher quality future developments is the mastering of digital systems as a creative working tool and using it in the professional environment. The research of these digital systems is essentially actual in Latvia, because so far they have not reached the comprehensive usage level if being compared to the world experience.

Current research level of the subject

Currently in the world there is sufficient amount of publications on the research subject, but in the Baltic scale there is no groundbreaking research that would affect the field of digital architecture. Migayrou Frédéric [111.] and Lebedev Juri Sergeevic [186.] in their books have compiled the beginnings of the non-standard architecture in the art of 20th century, as well as the early theoretical findings and experimental projects of bionics. The origins of Computer Aided Design in the field of architecture have been partly being systematized by Bozdoc Marian [203.], Reyes Jonathan [265.] and other authors [205.]. The transfer of military technologies in civil engineering is being mentioned in the archive materials of the Army of USA [189.]. The hybridization of architecture has been researched by Wolff-Plottegg Manfred [175.], his research is a rich illustrative manifesto without expanded theory.

The interaction factors of digital technology and architecture have been analyzed in the publications by Bermudez Julio and Klinger Kevin [201.], Kozak Paul [239.], Laiserin Jerry [94.], Langer Fred [96.], Mitchell William J. [112.], Winograd Terry and Flores Fernando [172.], Nesbitt Kate [116.], Ouroussoff Nicolai [124.], Cook Peter, Spiller Neil and Allen Laura [36.], Di Cristina Giuseppa [45.], Zellner Peter [182.] has given a resumptive collection about the pioneers of hybrid architecture in the digital age, but it does not exceed a level of popular illustration, it is missing an expanded and detailed theoretical grounding. Similar content is being written in the works of Liu Yu-Tung [103.], Constantinopoulos Vivian [35.], Aymonino Aldo and Mosco Valerio Paolo [10.], Brayer Marie-Ange, Migayrou Frédéric and Nanjo Fumio [21.], Jodidio Philip [80., 81.], Wells Matthew [171.], Nordenson Guy [117.], Dimster Frank [46.], Leach Neil, Turnbull David and Williams Chris [98.].

The digitalization aspects of architecture from a philosophical viewpoint or in relation to computation technologies is being analyzed by Chu Karl [209., 210., 33., 34.], Deleuze Gilles [43.], Corcó Josep [37.], Chaitin Gregory [208.], De Landa Manuel [41.], Chomsky Noam [32.], Latour Bruno [97.], Kolarevic Branko [91.], Rowe Colin [140.], Popper Karl [131.], Penrose Roger [128.], Rodych Victor [138.], Zeilinger Anton [293.], Lloyd Seth [104.], Lorde Audre [106.], Wittgenstein Ludwig [173., 174.], Wolfram Stephen [176.], Tschumi Bernard and Cheng Irene [163.], Spiller Neil [154.], Doesinger Stephan [47.], Fitelson Branden [59.], Flachbart Georg, Weibel Peter [60.], Freiherr Von Leibniz Gottfried Wilhelm [63.], Johnson Steven [82.]. Academic research and the results of workshops is being analyzed by Estévez Alberto [53., 55., 56.], Dollens Dennis [49., 50.], Hensel Michael, Menges Achim and Weinstock Michael [73., 74., 72., 170.], Cuff Dana [38.], Van der Veen Henk [165.], Yessios Chris I. [180.], as well as many other authors [225., 57.]. In these researches the generalization in the context of the subject's research line can be found as well as

academic experiments that have been obtained with the usage of digital architectural design tools.

The interaction of practice and theory in their scientific works (incl. master theses) has been reviewed by Keulemans Guy [86.], Wolski Jan [177.], Karsikas Antti [84.]. The achievements of several architects in international architectural exhibitions and thematically classified projects by regions have been reviewed by Bullivant Lucy, Gadanho Pedro [25., 26.], Buurman Marlies, Kloos Maarten [29.] and other authors. Several authors [211., 280., 291.] have described specific innovative and unique projects and their most relevant solutions or idea novelties: Neergaard Claus [252.], Somlyódy Nora [277.], Moreno Shonquis [114.], Giordano Carlos [66.]. However in the works of Alonso Hernan Diaz [192.], Rahim Ali [133.], Pisca Nick, Mah Jayson, Knight Hunter [261.], Fairs Marcus [226.] and More Thomas [113.] futuristic trends are being expressed. Several authors have described genetic algorithms and programming: Poli Riccardo, Langdon William, McPhee Nicholas Freitag [129., 95.], Goldberg David [67.], Lev Sara [244.], Haiman Eduard [294.]. The evolutionary computation has been researched in an advanced way by Hemberg Martin [71.], Eiben Agoston [51.], De Jong Kenneth [40.], Rozenberg Grzegorz and Salomaa Arto [141.], Kauffman Stuart [85.]. A great deal of publications depict a gnostic method of some particular design method (for example, genetic and algorithmic architecture): Oosterhuis Kas [122.], Del Campo Matias [42.], Bueno Ernesto [23.], Österlund Toni and Lundén Eero [123.], Mayne Thom [249.], Kolatan Sulan [236.], Zaera-Polo Alejandro and Moussavi Farshid [181., 115.]. There are authors that compare these software-coded algorithms to phenomena of nature, for example, the tonal patterns in animals and veining in plants, or they have researched the relation of natural forms and architecture in general: Menin Sarah and Samuel Flora [110.], Bahamón Alejandro [11., 12.], Pearce Peter [127.], Nouvian Claire [118.], Aldhous Peter [4.], Benyus Janine M. [14.], Botterweg Ilona [19.], Gánti Tibor [64.], Ingraham Catherine [76.].

Exact formal modus, approaches and methods are being analyzed more specifically in the books of Lynn Greg [107., 108.], Vyzoviti Sophia [167.], Reiser Jesse [135.], Gruzdy Sophia [70.], McCullough Malcolm [109.], Waters John K. [168.], Taylor Mark [160.], Aranda Benjamin and Lasch Chris [7.], Fear Bob [58.], not taking into consideration the complex architectural formal methods. The economical aspects of digital architecture is being mentioned by Appelbaum Alec [6.] because it is possible to save the resources being devoted to construction with contemporary software and preliminary analysis. The relation of architecture and other engineering sciences in their works have been reviewed by: Sasaki Mutsuro [145.], Schittich Christian [147.], Addington Michelle and Schodek Daniel L. [1.], Beukers Adriaan [16.], Kieran Stephen and Timberlake James [89.] as well as other authors [276., 215.]. Major part of

international publications are devoted to one or another ways of using particular design software [2., 193., 196., 197., 206., 219., 220., 69., 232., 248., 250., 253., 254., 264., 266., 275., 284.], as well as for achieving exact results: Rutten David [142.], Schliep Jan Walter [148.], Tedeschi Arturo [161.], Payne Andrew [258.], Akleman Ergun [3.], Issa Rajaa [77.]. Architecture being an art of making complex environment is significantly more difficult than any other visual form of art, therefore a general codification is needed on the possible ways about the synthetic usage of various software. Therefore in the spectrum of the current research the codification of this didactic material is slightly dominant, but the interconnections and main features have not been sufficiently systematized.

Subject of research is the usage of innovative and non-traditional digital architectural design tools, as well as the interaction of current theoretical findings with the design practice. In this research the digital systems are being defined as digital architectural design and manufacturing tools that are based on computer resources and tailored for architects or that have been borrowed from other engineering sciences, to facilitate and speed up all design stages from sketches till technical drawings with a precise information exchange between the involved professionals, as well as, to create all possible scale models and ready-made constructive or decorative building parts, visualizations or other virtual reality representation methods. The usage of such digital systems for a working instrument of an architect makes possible the implementation of contemporary architectural tendencies and ideas that earlier were not possible in the paper format or took unsubstantially long working hours with classical architectural design tools, and also by using laborious methods of descriptive geometry. Permanent experimentation by mastering the usage of new digital systems is the main driving-force for the further evolution and development of architecture, providing for the society always improved or more original solutions, ever incorporating the factors of sustainability and new modus of formal expressions.

The goal and tasks of the research

To research the novelty of digital systems and their usage extents in real architectural design in comparison to classical design tools, defining the main advantages and comparing their innovative possibilities.

Tasks to reach the set goal:

- specify the purposeful usage framework of these digital systems in the architectural design process;
- summarize European and world experience in the making of architectural projects and evaluate the advantages and main form creation methods of these digital systems in the creative process;
- concretize and supplement the necessary terms and definitions that have been used in an international communication discourse on digital architecture, and implement them into the usage of Latvian language;
- develop a complex system on the usage of digital systems to raise the quality of architectural design.

Methods used in the research

- the comparative analysis of papers, materials of international conferences or current practice curriculum that takes into consideration the historical or theoretical aspects and the design tools in the field of digital architecture;
- the comparative analysis of main parameters in digital design systems;
- the analysis of realized and conceptual projects related to the usage of digital systems;
- the comparative analysis of experimental proposals and existing experience, and theoretically experimental modeling based on various formal and spatially expressive studies of contemporary architectural tendencies for determining creative process and use an argued choice of instruments for obtaining concrete results;
- expert interviews with architects that in their practice are using the classical digital design tools;
- the statistical processing of the results from questionnaire that was carried out in Latvia and involved students, professors and practicing architects.

Scientific novelties of the doctoral thesis

- a comprehensive analysis that has been made first time and being based on international research on innovative and non-traditional digital systems used in contemporary architectural design, their advancements and progress;
- developed an analytic material on the position of digital systems in the creative process and about the usage principles of digital systems in the architectural design;
- a methodological recommendation complex created as the result of experimental modeling for synthetic usage of concrete software in the process of architectural design;
- analyzed possibilities and ways of how to localize the modus of world achievements to be implemented in Latvia.

Practical importance of the doctoral thesis

The achieved results of this research may be used in the practical architectural design as well as in the scale of urban planning in the work of the planning institutions, being suitable for graphical expression or in the search of new forms. The synthesis of digital architectural design tools has been accentuated. Part of the results have been implemented and may be used in the theoretical courses of the architectural studies, the supervision of the diploma projects as well as in certain specialized theoretical courses. The results of the research have been introduced to scientists, architects and urban planners in Latvia, Lithuania, Finland, Sweden, Norway, Spain and New Zealand. The main results of the research have been presented in various international conferences. During the research, a vocabulary of 38 new terms and definitions about the digital architecture has been composed – it is advisable to implement it in the usage of Latvian language.

Approbation of the research

The progress and results of the research has been regularly depicted in publications and scientific conferences. Author has prepared 10 publications on various digital systems in architectural design as well as presented in 11 international scientific conferences in Latvia and abroad.

Publications:

1. **Riekstiņš, A.** Ģenētiskās arhitektūras neierobežotās iespējas. *RTU Zinātniskie raksti : 10. sērija : Arhitektūra un Pilsētplānošana*. Rīga: RTU, 2008, 2. sēj., 194.–203. lpp.
2. **Riekstiņš, A., Briņķis, J.** Parametriskā pieeja lielmēroga pilsēt būvniecisko arhitektūras objektu projektēšanā. *RTU zinātniskie raksti : 10. sērija : Arhitektūra un pilsētplānošana*. Rīga: RTU, 2009, 3. sēj., 40.–51. lpp.
3. **Riekstiņš, A.** The Aspects of Parametric Design for Urban Architecture in the Age of Multi-Disciplinarity. *The Proceedings of Architectural Research 2009 : Architectural Research and Architectural Criticism Conference 23rd–25th of April 2009*. Trondheim: NTNU, 2009, p. 19–24.
4. **Riekstiņš, A.** Parametric Approach in Designing Large-Scale Urban Architectural Objects. *Science – Future of Lithuania : K. Šešelgis' Readings 2009*. Vilnius: VGTU, Faculty of Architecture, 2009, p. 22–26.
5. **Riekstiņš, A.** The Canvas of Fluid Urbanism and Liquid Architecture. *SLSA Textures 2010 : The 6th European Meeting of the Society for Literature, Science, and the Arts*. Rīga: SLSA, 2010, p. 11.
6. **Риекстиньш, А.** Преодолевая третье измерение. *Проект Балтия = Project Baltia*, 04/09–01/10, 2010, стр. 50–52.
7. **Riekstiņš, A.** Fluid Urbanism = Integrētā pilsētplānošana. *Scientific Journal of Riga Technical University : Series 10 : Architecture and Urban Planning = RTU Zinātniskie raksti : 10. sērija : Arhitektūra un Pilsētplānošana*. Rīga: RTU, 2010., Vol. 4 = 4. sēj., p. 90–94, 150.–152. lpp.
8. **Riekstiņš, A.** Animation Methods in Urban Planning. *International Conference of Biodigital Architecture & Genetics* [ed. Alberto T. Estévez]. Barcelona: ESARQ, 2011, p. 108–111.
9. **Riekstiņš, A.** Evolutionary Computation = Evolucionārā skaitļošana. *Scientific Journal of Riga Technical University : Series 10 : Architecture and Urban Planning = RTU Zinātniskie raksti : 10. sērija : Arhitektūra un Pilsētplānošana*. Rīga: RTU, 2011., Vol. 5 = 5. sēj., 7 lpp. (accepted for publishing)
10. **Riekstiņš, A.** Steps Towards Genetic Architecture. *International Scientific Conference Ecological Architecture 2011*. Kaunas: KUT, 2011, 6 p. (accepted for publishing)

Presented papers in conferences:

1. „The Aspects of Parametric Design for Urban Architecture in the Age of Multi-Disciplinarity“. International conference „Architectural Research and Architectural Criticism“ in Trondheim, Norway, 24.04.2009.
2. „Parametrinis požiūris stambiu urbanistiniu architektiniu objektu projektavimo srityje“. International conference „The Scientific Readings of K. Šešelgis“ in Vilnius, Lithuania, 08.05.2009.
3. „Parametriskā pieeja lielmēroga pilsēt būvniecisko arhitektūras objektu projektēšanā“. RTU 50th international scientific conference „Identity and development“ in Riga, 13.10.2009.
4. „Digitaalinen arkkitehtuuri käytännössä“. International conference „Generate – Algorithmic Architecture“ in Oulu, Finland, 29.10.2009.
5. „Parametriskā pieeja pilsēt būvniecisko struktūru veidošanā“. University of Latvia 68th international conference „Spatial planning and development“ in Riga, 05.02.2010.
6. „A Vision for Digital Media in Interdisciplinary Architectural Design Education“. Victoria University of Wellington in New Zealand, 19.05.2010.
7. „The Canvas of Fluid Urbanism and Liquid Architecture“. International conference „SLSA Textures 2010 – The 6th European Meeting of the Society for Literature, Science, and the Arts, Architextures“ in Riga, 16.06.2010.
8. „About Research of New Digital Systems in Contemporary Architecture and Possible Futures“. Baltic Architect's Union Association (BAUA) 20th anniversary international scientific conference in Riga, 01.10.2010.
9. „Fluid Urbanism“. RTU 51st international scientific conference „The global and local identity of the city scape “ in Riga, 08.10.2010.
10. „Towards which urban planning architecture should we be heading in future?“ International conference „Yearly seminar for the heads of Finnish urban planners of all the main Finnish cities“ in Helsinki, Finland, 07.04.2011.
11. „Animation Methods in Urban Planning“. „International Conference of Biodigital Architecture & Genetics“ in Barcelona, Spain, 03.06.2011.

Amount of the research

This doctoral thesis has been written in Latvian language and its total amount is 296 computer layout pages. It includes 180 images and 5 tables that depict the textual part of the research. Thesis has 4 annexes as well the list of references that contains 294 titles.

ANALYTICAL PART CONTENTS OF THE RESEARCH

First part of the doctoral thesis researches the theoretical findings in the digital architecture and the possibilities of the digital design tools. Classical, innovative and non-traditional digital tools have been analyzed. The result of the architect's work can significantly be affected by his working tools and the skills needed to master them.

First chapter of the first part researches the history of the Computer Aided Design (CAD). The beginning of CAD initiates from the USA, where military industries firstly implemented the Numeric Control (NC) in the fifties of the 20th century for automatizing the work of metal processing machinery and exceeding the constraints of mass production. In the next decades together with the developments in the field of computers new Computer Numeric Control (CNC) systems were introduced, they were mainly used for processing different materials in various scale of production. However, Computer Aided Manufacturing (CAM) became widely available only in the eighties at the time when personal computers became more affordable and CAD software was already used in a broader scale.

Second chapter of the first part codifies and analyzes the theoretical findings of the digital architecture. The notion of architecture currently is obtaining new definitions because its essence and conception has been changed. Architecture evolves together with the changes in society, science and politics. In the world there are many opinions and viewpoints that in the case if not being particularized it is hard to understand what stands for the so-called new expressions. New digital architecture that has been made utterly with computerized graphical tools has developed to such a scale that we may freely admit – digital organicism is the avant-garde of the early 21st century. Serious and innovative research has been carried out in this field in the leading schools of architecture, for example, in Massachusetts Institute of Technology (MIT), University of California, Los Angeles (UCLA), Southern California Institute of Architecture (SCI-Arc), The Royal Melbourne Institute of Technology (RMIT University), Universitat Internacional de Catalunya in Barcelona (UIC), Delft University of Technology (TU Delft), University College London (UCL), Architectural Association School of Architecture in London (AA) etc.

Third chapter of the first part analyzes the most common classical design tools of digital architecture. They can be considered such software that historically has been made and developed to facilitate the drafting process in the shift from hand-drawn to digital drawings. Originally this software was universal and equipped with main drawing tools of descriptive geometry, therefore being suitable for all the engineering sciences that needed drawing. Such software specifically for the needs of architecture started to be developed together with the early appearance of *ArchiCAD* in 1982–1985. Their main differences included specialized tools palettes suitable more for the architecture. Most of the classical digital design tools are good and deliberative products to make working drawings and other visual material needed for daily design tasks. *AutoCAD* is the most widely used *CAD* software and meantime also the market leader in this segment. Whereas *ArchiCAD* has been developed and polished especially for architects needs since its very first version. The leading architecture design tools are lacking the link of *CAD/CAM* for the use of three-dimensional computer manufacturing in the architecture.

Fourth chapter of the first part analyzes the innovative and non-traditional systems used in architectural design – the software products, their plug-ins and *CAM* hardware. These systems include an essential *CAD/CAM* functionality, supporting the realization of unique projects. Besides this functionality makes possible to realize such ideas that have been theorized and researched for almost last fifty years. Combining the possibilities of these tools with the creative thinking, many architects in the world that are practicing progressive architecture have came up with buildings and other objects of unimaginable complexity, that sometimes with their simplicity and originality surprise and is pointing towards a continuous evolution of architectural science. Some of the main milestones – parametric architecture, scripting and generative design methods. They have become more available now when personal computers have reached serious parameters of computing power. These kinds of tools have already started to change the architectural processes – creating new directions and global tendencies. Analyzing the *CAD* and *CAM* supplementary hardware tools it may be concluded that all of them have been initially used in the fields of military industry and industrial design (rapid prototyping, *CAM*, laser cutting, 3D scanners, photogrammetry method etc.). Although also these tools need good skills to be used, because various fine nuances have to be taken into account, for example, how to optimally measure objects of complex configuration and how to post-process the data for further usage in the design process. The architect's work with these tools is technically more precise and advanced – therefore also with a higher responsibility.

Second part analyzes the projects for which there has been a need to use digital architectural design instruments. Analyzed objects are grouped in two chapters – worldwide and in the context of Baltics. By analyzing the factual information it has been established how deeply various methods of digital systems has been used so that they could give efficiency or – with what tools one would have to be working to make the design or manufacturing processes more effective time- and quality-wise.

First chapter of the second part analyzes the most significant architectural projects worldwide, where the innovative digital systems have been used. Such projects have been chosen where there has been a need to use some of innovative or non-traditional digital design or manufacturing tool for their realization. The reviewed projects of this chapter are one of the most expressive objects worldwide, and analyzing them lets conclude what methods have been used to create them.

Second chapter of the second part analyzes the tendencies of digital systems in the regional context. The major accent is set on projects in Latvia as well as in examples from Estonia and Lithuania. In the *Pro Inno Europe* published statistics on performance of innovation and the analysis results in 27 European countries – most important indicators that also affect the field of architecture depict that, for example, Latvia is behind Estonia with its scientific system by 7,2 times, with finance and support systems by 5,4 times, with the link of science and entrepreneurship by 14,5 times, as well as with the innovation of companies by 19,3 times. Estonia is in the group followers to 10 leading European innovation countries, whereas the position of Latvia at the very bottom of this statistics testify the fact of accumulated problems in the country at the same time pointing to the potential chance of growth. In the framework of this doctoral thesis there was made a questionnaire to find out the point of view by Latvian architects on their work, education, sources of inspiration, styles and other issues related to digital systems in architecture. That provided important answers about the practical side of architecture in Latvia, that helps to understand the general posture and orient the results of the research towards the usability of digital systems in the practice of Latvian architecture. In chosen examples of regional context the innovation level was evaluated and there were given advices what could have been done in a more effective way if the innovative and non-traditional systems would have been used more, or in some cases – implemented at all.

Third part is devoted to the potential usage possibilities of theoretical and practical findings in the architectural design. The experiments made by author and reviewed here are part of the practical research on digital systems in architecture and their unlimited possibilities, applying new and non-standard design methods from innovative theories of the contemporary architecture. The fundamentals of all various

design methods are scientifically rooted ideas that have been incompletely researched before but their input enriches the field of contemporary architecture, offering completely different breadth of view in non-standard design situations. In the framework of experiments author offers new methodology – a complex system on the usage of digital systems to improve the architectural design qualities, esthetic value, technical possibilities and other factors.

First chapter of the third part researches the design possibilities of genetic architecture and explains an author's experiment that has been made with this method. Both the genetic and DNA computing processes are being cross-bred with the creation processes of architecture in a hybrid way, thus creating a new stage of architectural evolution. During the experiment there was tested a process that involved algorithmic actions and the final result was interpreted into a 3D object. Genetic architecture, being one of the youngest design approaches, gives infinite possibilities in search of new architectural forms.

Second chapter of the third part analyzes the parametric architectural design and an author's experiment, offering a complex system tool for designing large-scale urban objects. The developed tool has a vast usability capacity, in future it may be reprogrammed and updated, so that it would serve for a real working tool and could be implemented in the design practice. The work in parametric architecture is being done by using software that initially was developed for aircraft design and the progressive engineering, where many simultaneous changes in the project may be made, beforehand setting up the relations between objects, seriously saving the time needed for making the changes.

Third chapter of the third part analyzes the design of evolutionary computation and an author's experiment with the plug-in *Genr(8)* of the 3D modeling software *Maya*. During the author's experiments, the plug-in *Genr(8)* was mastered to find out the possibilities for morphogenesis, "growing" digital evolutionary algorithms. Also the genetic growth was researched, finding a suitable conceptual spatial architectural configuration between two surfaces. The base for design was an in-depth testing of various evolutionary units, until a satisfactory and suitable result was found with architectural treats. This experiment has proven that the evolutionary computation has a major potential in creating new computer-grown forms.

Fourth chapter of the third part analyzes an experiment made in context of the author's research with topological modeling software and *CAM* hardware. The constraints of modeling software were researched thoroughly to realize a small conceptual project – a flower pavilion. At the same time it was an exercise to see the specifics of biomorphic architectural design, imitating visual and constructive systems

from the nature, but in this case only with contemporary technologies and materials. Some important aspects during the experiment were also discovered on preparing drawings and renderings for 3D objects. This experiment included the work with new kind of materials and solutions for technological fabrication. Meanwhile also the possibilities to preserve the purity of geometric form with a minimal degree of detailing were checked. Also the author got convinced that by mimicking the nature's structures, topology and visual looks, an ornamentally rich general image can be created.

Fifth chapter of the third part researches the fluid urbanism method and architectural animation that is based on real planning structure. The author's experiment gives a wider overview and possibilities to solve the spatial quality issues, using the advantages of 3D modeling to control the form and model the changes of geometry in real time. The architectural animation methods in combination with scripting offer significantly more ways to solve the urban planning issues from another viewpoint.

Sixth chapter of the third part analyzes the algorithmic architecture, scripting and generative design methods, as well as an original author's experiment. The algorithmic design is related to computer software that is used to create space and form from rule-based logics of architectural program, typologies, building law and the programming language itself. To make such approach easier to be used, special scripting languages have been created, that are available and bundled with 3D modeling software. Algorithmic architecture is not only about the mastering of programming language or a system, but at the same time a new way of thinking in design.

Annexes codify author's terminology that has been mentioned in the doctoral thesis, and its definitions are explained with an intent to understand directly and in a simple way the nuances between various meanings that in the architecture of Latvia have previously been used seldom or not at all. In addition the annexes include the questionnaire of professionals that was made in context of this research, interviews with architects and the table of comparative analysis for innovation performance from year 2010 in 27 European countries.

CONCLUSIONS

1. The innovative design software change the classical point of views on the making of architecture and it gives a possibility to design in a radically different ways from the habitual ones.
2. To realize unique and modernized projects it is necessary to develop and use new kind of design strategies.
3. The variety of creativity is being encouraged by the advantages of innovative and non-traditional digital systems. New digital tools are non-replaceable potential for creating unique forms.
4. The usage of contemporary technology ensures a possibility to recognize the multiplicity of nature's form palette and it makes possible its usage for a source of inspiration. Nature encounters many varied forms that have distinct features of modern architecture. For modeling complex forms the skills of highest mathematics are essential.
5. To fabricate building elements of complex configuration, it is necessary to support exact and successive compatible usage of various digital systems (for example, precise steps between parametric design, 3D model, point cloud etc.).
6. In the realization of most difficult form creation of contemporary architecture, the computer equipped with special software is a non-replaceable tool to analyze spatial object multi-dimensionally and to obtain a fixed project documentation.
7. To support a thorough social role, a harmonic interaction is needed between modern computer technologies in architectural design, contemporary engineering sciences and the production of building materials.
8. Various experimental design methods and tools that have been developed can be used to make sustainable projects, offering more rational solutions or a chance to save on design or manufacturing costs and taking into account the contemporary architectural form creation tendencies.
9. In the regional context the architecturally spatial environment development so far in the state level has not been paid a proper attention, also not fostering the implementation of innovative and modern technologies in conformity with the world level.
10. The adoption of innovative and productive design technologies (specialized CAD/CAM systems, methodology of software and computerized fabrication technologies) needs to be implemented in the study programs of the Latvian national school of architecture. In the education it is needed to have intensive workshops and theoretical lecture cycles on new tendencies and methods in design; cooperation in academic level must be fostered between the leading schools of architecture in the world and also interdisciplinary contacts have to be developed with the fields not straightly being related to the architecture.

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