MOKSLAS – LIETUVOS ATEITIS 2009, 1 tomas, Nr. 2
SCIENCE – FUTURE OF LITHUANIA 2009, Vol. 1, No. 2

K. Šešelgio skaitymai – 2009
K. Šešelgis' Readings – 2009

PARAMETRIC APPROACH IN DESIGNING LARGE-SCALE URBAN ARCHITECTURAL OBJECTS

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Summary. When all the disciplines of various science fields converge and develop, new approaches to contemporary architecture arise. The author looks towards approaching digital architecture from parametric viewpoint, revealing its generative capacity, originating from the fields of aeronautical, naval, automobile and product-design industries. The author also goes explicitly through his design cycle workflow for testing the latest methodologies in architectural design. The design process steps involved: extrapolating valuable statistical data about the site into three-dimensional diagrams, defining certain materiality of what is being produced, ways of presenting structural skin and structure simultaneously, contacting the object with the ground, interior program definition of the building with floors and possible spaces, logic of fabrication, CNC milling of the proto-type. The author's developed tool that is reviewed in this article features enormous performative capacity and is applicable to various architectural design scales.

Keywords: parametric architecture, associativity, bottom-up design, statistics, GIS, multifunctionality.

Introduction

Today all the disciplines of various science fields are converging and developing. Nowadays we can even say that architecture involves and can be linked to almost any field, nevertheless, is it science or fiction? It means that a contemporary architect must keep up with any advances in all possible fields of science and technology. The author underlines that without experimenting with the latest tools we may run into self-repetition and loss of innovativeness. Thanks to Peter Eisenmann, today we approach a project and we explain processes. He is interested in process, its purity, the capacity of this formal language to prove things, generation of meaning signification. Final result is really not important. Nowadays, with contemporary approaches meaning is the same as before, only the new generation of advanced architects now use 3D modeling software instead of cardboard. Now architects have the power of software and the power of NURBS[1]. The formal system depends on how many rules you have. Logic behind generative form is the same, based on works or understanding on Chomsky[2] and computers, on and on back to Palladio.

Approaching Digital Architecture from Parametric Viewpoint

The parametrically associative software is probably one of the best ways to express complex relations, resulting in harmonic proportional systems. Such a software is used in airplane design (for example, Boeing, Airbus, French Mirage Jet etc.) and advanced engineering, where many simultaneous changes in design can be fixed by setting up relations be-forehand. In fact, the whole set of rules is built up in a system that can be expanded practically to infinite, where the only limitations are those set by hardware processing (nowadays it is not concerned as a limit any more). Complex systems are also introduced in architecture of computational systems, and they are being developed all the time.

Most often the utilization of parametric models in the field of digital architectural design reflects the fact that much of the architectural soft-ware in use today was originally developed for the aeronautical, naval, automobile and product-design industries. Due to an inherited emphasis on maintaining geometric control and workflow efficiency, the parametric models used in these programs are embedded with processes and constraints, which lend themselves to the post-rationalization of complicated building geometries derived from other design processes. In architecture, deploying parametric control is primarily geared towards processes of rationalizing complex geometries, the typical case being the doubly curved façades

1 *NURBS – non-uniform rational b-splines, author's comment.*
2 *See the work about the generative grammars in a book by Chomsky, N. 1975. The Logical Structure of Linguistic Theory. Berlin: Springer. 604 p.*

ISSN 2029-2341(print)/ISSN 2029-2252 (online)
http://www.jmk.vgtu.lt

rationalized as a parametrically defined system, which can then be relatively quickly adapted to inevitable changes in the overall scheme. The geometric data relevant to manufacture and construction is contained within this parametric model and is therefore effortlessly recalculated and retrieved. Indeed, the skills for achieving the geometric complexity found in many recent "iconic" buildings have long existed but are only now, through the process of parametric post-rationalization, becoming affordable. Not dissimilar to the alternative use of CAM[3] as a generative and integral driver in the design process, associative modeling can provide a critical cornerstone in the development of an integral design based on material systems rather than being a merely facilitative tool (Hensel 2006: 43). The underlying logic of parametric design can be instrumentalized here as an alternative design method, the one in which the geometric rigour of parametric modeling can be deployed first to integrate manufacturing constraints, assembly logics and material characteristics in the definition of simple components, and then proliferate the components into larger systems and assemblies. This approach employs the exploration of parametric variables to understand the behavior of such a system and then uses this understanding to strategize the system's response to environmental conditions and external forces.

Curved surfaces yield great potential for architectural design. This potential is both geometrical and topological, with significant repercussions on the design, production, behavior and effect of material form (Hensel 2006: 39).

At an international architectural conference about emerging architecture held in Barcelona in April 2008 during the final discussion board famous masters of digital architecture Bernard Cache, Evan Douglis and Ali Rahim announced that AutoCAD had to be considered as a dead soft-ware having no place in future architecture because architects can create with it only weak and old-fashioned architecture (Riekstiņš 2008). The author's proposals differ from other CAD approaches by its distinct distance from the traditional workflows and possibilities limited by constraints, set up by narrow choices of ready-made tools, typically included in the mainstream architectural CAD software.

Design Cycle Workflow

In the workflow the author experimented by choosing strategy, not exactly the form to design a large-scale urban architectural object – multi-functional center. Form Finds Function. With these three words the de-sign project could be described in the best way, and by using diagrams and strategy an appropriate form was found (Riekstiņš 2008). Such a methodology of working in contemporary architecture is also called "bot-tom-up" design, whereas standard architectural design with an exact object volume definition, defining needs for spatial configurations already in the design task, is known as "top-down" design. It was expected that this project would include both synthetically critical and analytical investigations in the field of genetic workflow, emergent systems, new technologies and also in the use of maximum computational power. The design task was to resolve a complex space with varying program, multifunctionality and new strategies for design. Once this project was finished, it resembled a cycle, which could be re-run. That is because the clear work-flow allowed rich and multiple variations at every step.

Cities are complex systems. The flow of vehicles and people within a city represents the emergent behavior of such a system, produced by large numbers of decisions of individuals, and their interaction with each other and with the transport infrastructure of the city. Complex systems are, by definition, nonlinear and sensitive to initial conditions, so that small changes in such conditions may produce turbulent behavior at the global scale (Weinstock 2006).

The first step involved an observation of processes going on in Lesseps square, the location for the project, which is probably one of the most complicated urban junctions in the city of Barcelona, Spain. It contains lots of traffic flows and people rushing from point to point. Al-though there exist lots of problematic squares like this in the cities of Latvia as well, the author chose particularly this location for three reasons: 1) due to its complexity in the urban context; 2) availability of statistical data ready to be utilized in the project; 3) because this square currently is being rebuilt, and the author decided to propose his vision on solving it in an alternative way.

The second step involved data collection and raster mapping by GIS[4] principles. Different kinds of data were analysed from various information sources to find data that could be used for further working. Information about traffic and people's movement was chosen for further work. Using the principles of GIS, vectorial data from an area of 34.4 hectares (630×545 meters) was raster mapped to Excel spreadsheet, choosing data matrix size of 45×39 cells, which is mere 1755 different cell units in each of the spreadsheets. The reduced raster cell size for

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[3] CAM – Computer-Aided Manufacturing, author's comment.

[4] GIS – Geographic Information Systems, author's comment.

this GIS system was 14×14 meters. Any relevant linear information data was interpolated between these cells. To simplify further work, all various data types of amount of cars passing Lesseps, pollution in grams of CO_2 per km^2, noise in decibels, amount of people, speed in km/h and density of people per m^2 was interpolated to digits from 1 to 5, with ability to calibrate them in six different spreadsheets at a time just changing these digits once.

In the third step the author's work involved serious Excel inter-calculation programming to build a data-driven tool, which could be applied and interpreted in almost infinite possible ways. The possible use could be parameters for associative models, geometric form generation or any other kind of 3D manipulations. As the chosen amount of data seemed to be too big for a research project like this, margin of usable data cells was introduced. Cells which cover Lesseps square and its surround-ing buildings with slight influence extension outwards the square set up the border condition. The final Excel spreadsheet tool included fine-tuning ability wherein any of six data calibration levels from 1 to 5 can be changed at once by doing it in one place. This tool was an ideological base for continuing the work (Fig. 1).

The fourth step was the surface generation with the help of a parametric base grid. Here the author continued on testing the infinite possibilities of parametric software Top Solid to construct a system for surface generation. Numerical data of three information sources about cars and three information sources about people were separated, so that each of them was generating an independent 3D mesh of points where the two resulted meshes stand on the top of each other, irrespective of the size of diferentiation that is introduced by calibrated parameters. The base points were set on a regular square grid, following the precise position of the data in the GIS system. Surface construction logic imports spreadsheet data of GIS, distributing it in two levels. A part of the data drove points up, while the other drove them into circles and then triangles. The triangle lowest right and top sides were connected, and in this connection line a new center point was found. Using three such center points a new surface was represented in a 3D space, connecting all of the elements together. Lower triangulated surface represents cars, while the upper one represents people. Specific inter-calculation equations were used later for fine-tuning the desired result, keeping the basic logic in a strong parametrically constructed model.

The fifth step was experimenting with various shapes that could be built in between two of generated 3D meshes of points. One of the options was producing two tetrahedrons that were intersected together and new membrane openings were made at their intersection places. Another option included triangulated curves that were connected at two points and they formed a membrane with openings between cells. Another very complex option with 480 length parameters resulted in a cell between 7 points of the 3D mesh. A part of the cells split, and a part of the cells touch forming a solid geometry. A certain similarity to flowers could be drawn, while openings and any dimensions were strictly configurable to different performative features. The author finished time-consuming tests with simple yet complex four-sided cells that have a hole in the middle. Unfortunately, after data import linking nothing of this system worked and the work on fixing parametrically associative errors was continued after the next step.

The sixth step – system calibration and spatial definition. The experiments prove that even the smallest error ruins the system, so to apply it to the design process meant reasoned decisions on how to proceed further. The most elements that worked well from previous tests were set up in a new system, where certain new rules controlled how the parameters should behave. By testing on simple two triangulated meshes how the data-driven Excel tool generated space, more fine-tuning was needed to fix zero conditions with error correction values. Once linked with along-side developed TopSolid system, the possibilities just started to give a clue how rich spectrum of design choices was open (Fig. 2).

Think of birds in a swarm. The birds are executing a basic flocking rule, like checking the position of their neighbors all the time. As long as they are swarming, they keep on checking, they never let the distance be-come too big or too small. People in a crowd perform similar behavior; they do avoid collisions by constantly checking the positions of immediate neighbors. (Oosterhuis 2004: 29) The description of a swarm best matches with the seventh step – Top Solid construction logic of cells and their parameters.

The eighth step was going further to understand the ways of how to make a model of the project. The author chose to make it from the basic components in scale 1:100. The geometry itself was in a way complicated, because it holds together in corners and the internal space frame, which is formed from the structural floor elements. To facilitate the assembly, the author chose a strategy to make the model by triangulating the geometry to simple planes and then unfolding them and enumerating the edges. The next step involved a research on how to produce the necessary components with the help of CNC machinery.

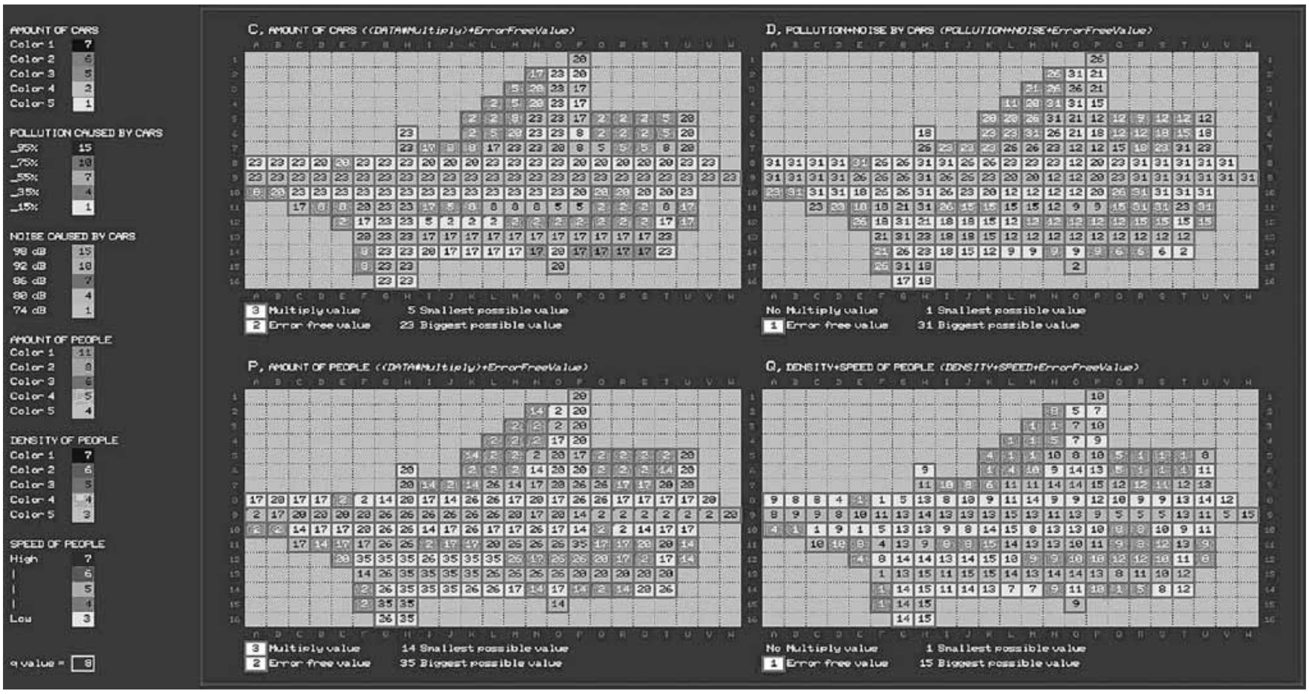

Fig. 1. Author's developed Excel spreadsheet tool (Image: Arne Riekstins)

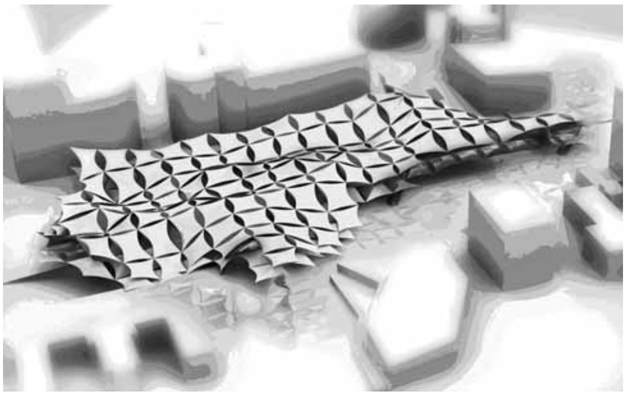

Fig. 2. Multifunctional center in Lesseps square. Object blends in with its shape to the square with the utmost respect to the surrounding (Image: Arne Riekstiņš)

A cell consists of 24 triangles; each side of a cell component is formed out of three triangles. Basi-cally, the project was so big that the author decided to make only one, the Western part of the model, which shows all the possible cell conditions and spatial configurations, consisting of 319 millable pieces. Chosen ma-terial was 1 mm thick polypropylene and there was no way to let the ma-chine cut the bending lines from inside and outside, so another half of the work needed to be done by cutting manually. Milling process was per-formed on a machine, produced by Axyz Corporation, and all millable pieces were converted to a machine-readable format, through AutoCad DXF R12 Natural file format. The usable drill was 2 mm in diameter, so 1 mm of compensation was needed to fix possible cutting errors. The assembly took two weeks.

The ninth step was the planning for spatial configu-ration use. As the bottom-up design process involves a different way of thinking and under-standing processes in architectural design, calibration of the system and statisti-cal data produced a mutual planning all the time. Where there is a lot of traffic, building is elevated from the street level, and more people mean that at that point there is more spatial volume at the building.

The author distinguished seven main usable space groups as seen from above to below: an internal roof-level space that can be used for recreational functions and conferencing, open air terraces for cafés and bars, the upper service level for utilitary communications such as ventilation, etc., office space units in the cells that unite into one closed cluster, multifunctional space for exhibi-tions and theatres or cinemas (the biggest open space in the area of splitting cells that can be best seen in the sliced tomography sections (Fig. 3), a lower service level for utilitary communications like water and sewage, etc., support legs for access with stairs and other vertical ac-cess communications. More to that there are planned but still technically unresolved underground areas with park-ing allocations. For a building, which covers the size of

Fig. 3. Project's sliced tomography sections, revealing the biggest open space in the area of splitting cells. (Image: Arne Riekstiņš)

almost four football fields, the aforementioned space makes up 14 412 m^2, out of which usable space is 10 240 m^2. This building features a variable height with a maximum up to 20.8 m from the street level. Calculating roughly, such a building can provide around 1 075 new workplaces, which is a significant number for such a relatively small square in the city.

Dynamics and a free flow of the curvature amongst other illustrative terms are just some words to express this architectonical object that blends into cityscape with the utmost respect to the surrounding and the most relevant proof of a concept, based on real statistical data. The object was obtained by 99% responsive parametrically associative design, where no subjective decisions of the designers are put in anything else than de-signing of the whole system (Fig. 4).

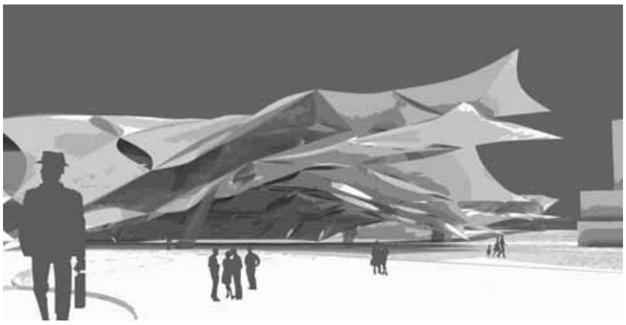

Fig. 4. View from the street level. Building blends with the surrounding (Image: Arne Riekstiņš)

Conclusions

1. The end can be the beginning. Once the designing of a particular system is finished, it starts living and giving infinite possible futures. Whereas with the traditional designing, when you finish the design, it is the end of the project.

2. For the design process, there are a lot of facilitative drafting and modeling softwares, but they are not generative or creative in any sense. So, developing his own system for a strong tool with a huge usability factor in future is the author's biggest achievement in this research experiment.

3. The author's designed tool is a device with an enormous performative capacity, re-programmability and possibility to expand it in the future.

4. Aesthetic quality of the obtained project result with its blending into the surrounding is a good example of a parametric approach to such problematic urban locations like Lesseps square in Barcelona. It allows the new object to preserve the existing infrastructure without being an obstacle in the sense of context. The appeal or dislike of its aberrant appearance is up to the taste of the observer.

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PARAMETRINIS POŽIŪRIS STAMBIŲ URBANISTINIŲ ARCHITEKTŪRINIŲ OBJEKTŲ PROJEKTAVIMO SRITYJE

A. Riekstiņš

Santrauka

Dingstant riboms tarp skirtingų mokslo sričių atsiranda naujų požiūrių į šiuolaikinę architektūrą. Autorius pristato skaitmeninę architektūrą, perėmusią aeronautikos, jūrų, automobilių, dizaino objektų principus ir gebančią generuoti. Savo nuostatas autorius sugretina su naujausiomis architektūrinio projektavimo metodologijomis. Siūlomas projektavimo procesas apima šiuos etapus: vertingų statistinių duomenų apie sklypą ekstrapoliavimas į trijų dimensijų diagramas, planuojamo medžiagiškumo nustatymas, tuo pat metu pristatoma konstrukcija ir struktūriškas apvalkalas, objekto kontaktas su pagrindu, siūloma interjero programa su pastato aukštais ir erdvėmis, statybos seka, prototipo gamyba. Autoriaus straipsnyje aprašytas būdas pasižymi ypatingomis atlikimo galimybėmis ir yra pritaikomas įvairių architektūrinių objektų projektavimui.

Reikšminiai žodžiai: parametrinė architektūra, asociatyvumas, nuo smulkmenų prasidedantis projektavimas, statistika, GIS, daugiafunkciškumas.