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PROTOTYPICAL ARCHITECTURE

Design research method with full-scale models

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Abstract. This paper will discuss the role of the prototype in the design process, in the context of adaptive principles and iterative procedures. The starting point of this study will be the analysis of several recent projects from THEVERYMANY™ and their concept of "prototypical architecture". This paper aims to give an insight into both a different conception of architecture and the specific ways of research-oriented work which have redefined the role of the prototype in the design process. In the analysis presented here, the role of computer-aided architectural design is seen as fundamental in the development and further improvement of the iterative design process through faster and more affordable construction of prototypes.

Keywords. Prototype; prototypical architecture; iterative design process; full-scale model.

1. On exactitude in science

"In that Empire, the Art of Cartography attained such Perfection that the map of a single Province occupied the entirety of a City, and the map of the Empire, the entirety of a Province. In time, those Unconscionable Maps no longer satisfied, and the Cartographers Guilds struck a Map of the Empire whose size was that of the Empire, and which coincided point for point with it. The following Generations, who were not so fond of the Study of Cartography as their Forebears had been, saw that that vast Map was Useless, and not without some Pitilessness was it, that they delivered it up to the Inclemencies of Sun and Winters. In the Deserts of the West, still today, there are Tattered Ruins of that Map, inhabited by Animals and Beggars; in all the Land there is no other Relic of the Disciplines of Geography". (Borges 1946)

2. Prototypical architecture

Over the past few years, quest for The New has led architectural avant-garde to engage in relentless production of prototypes in the form of full-scale models made for the purpose of testing various ideas and processes. Obsession with the diagram, dominant over the previous architectural discourse is now replaced with a working method encompassing construction of models at their own scale. Costly as they are, often utilising a wide spectrum of computer-aided architectural design and manufacturing systems, these prototypes do not have utilitarian purpose; e.g. they do not necessarily provide shelter of any kind. The reason for constructing them also surpasses pure sensorial engagement. Their purpose is equally remote from the representational role of architectural maquette, and the need to transform the viewer's perception which is central to art installations. Nature of prototypical architecture is purely research-oriented; it is set to operate in the territory not yet visited by the contemporary architectural practice.

The term "prototypical architecture" comes from Marc Fornes (2011), who is using it to explain design and construction of projects which he produces in sequences. Under the pseudonym THEVERYMANY, he has been working in the field engaging both architecture and computation to explore new possibilities in morphologies, materials and assembly techniques. Many of such experimental projects are now built and provide valuable research material for this topic. His ideas are related between themselves, and their development may be observed through several continuous streams of investigation. Their sequential order provides evidence of the concept evolution and methodically documents building technique development. To provide an account of this assertion, I will look into four recent and completed projects of THEVERYMANY: n|Edg, n|Strip, Y/Surf/Struc and nonLin/Lin Pavilion.

2.1. Y/SURF/STRUC CASE STUDY

In 2011 Y/Surf/Struc, now part of the permanent collection of the Centre Pompidou, was conceived as an experiment with a self supporting surface morphology whereby structural members are opening up and lending themselves to a surface condition. Its geometric logic explained by the author is a combination of two distinct systems, distributed and hierarchical, resulting with what is referred to as 'Y' model (Fornes 2011). Entire surface is made of tripartite segments tapping into each other and making it very difficult for the eye to distinguish between the part and the whole. Initial modeling is done in relation to immediate surroundings and in regards to the structural considerations of the most suitable supporting points in the given environment. Secondly, surface curvature is controlled and amended to allow for more optimal materialisation. Both conception and fabrication of such model are heavily dependent of computational protocols as surface is being continually reconstructed in the process of search for the most viable solution. Surface geometry is understood and described through a large number of referential points whose densities are relative to the degree of curvature. Greater surface curvature results with more points and consequently finer tessellation will results with more parts in the fabrication process. In the end, surface is converted into a number of developable elements which can be unrolled and cut out of flat sheet material, in this case aluminum.

2.2. N|EDG AND N|STRIP CASE STUDY

Figure 1. N|STRIP by THEVERYMANY.

The understanding of the surface morphology through custom computation and digital fabrication has been central in THEVERYMANY work for number of years. The method requires intricate work on the intersection of several disciplines. In 2009 n|Edg model has tested a novel procedure in describing complex surfaces with flat components by replacing standard triangular elements with polygonal ones defined by n number of edges. When put to work, such solution with lesser number of parts and joints resulted with quicker and easier assembly process. Consequently, in 2010 n|Strip model was driven with the similar idea of economising on the number of components. It employed a protocol to reconstruct a surface with a smaller number of developable elements, this time organised as linear stripes (Fornes 2010). In result, the construct was assembled much faster. Both n|Edg and n|Strip projects have already showcased aspects of the Y model geometry and have been important milestones in its development, both providing knowledge necessary for its construction. In the meantime THEVERYMANY has carried out other related experiments, using different materials and tessellation techniques which have yearend valuable information but have not lived to the same expectations. For instance, construct of walnut veneer, made for the Union Square in New York, collapsed under its own weight before reaching its destination.

2.3. NONLIN/LIN PAVILION CASE STUDY

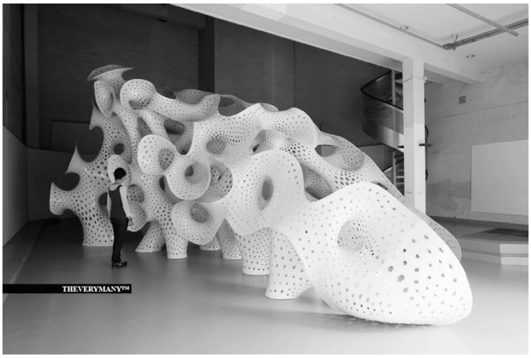

Figure 2. NONLIN/LIN PAVILION by THEVERYMANY. Photo Francois Lauginie.

Finally in 2011, nonLin/Lin Pavilion, now part of the permanent collection of the FRAC Centre in Orleans, once again synthesises experiences acquired in the previous experiments and uses surface paradigm to generate spatial environment. Here too, understanding of the complex surface morphology is essential to the design process. Reusing the knowledge acquired in the previous iterations of the Y model idea includes techniques used for representing surface as information that can be translated and materialised into a series of planar stripes ready to be cut out of the flat aluminium sheets. Yet, there is no universal procedure to resolve every tessellation problem. Instead of the global application strategy of populating discreet components onto an overall host, the approach relies on the coordinate use of multiple and simultaneous codes (Fornes 2011). In other words, overall surface model goes through the process of recombination. It is continuously divided and then put back together, altering between the states of subdivision and union, until satisfactory solution has been met. State of subdivision allows for the multitude of specificities to be dealt with differently and in accordance with local conditions. State of the union provides for synchronisation of otherwise dipartite segments. The author describes the Pavilion as a “non-linear structure” (Fornes 2011), alluding to the morphological condition of change, similarly to what is used in the science of physical cosmology to explain formation of large scale structures.

2.4. CASE STUDY CONCLUSION

In conclusion to this case study analysis, the concept of "prototypical architecture", as used in this paper, establishes profoundly different conception of architecture and specific ways of research-oriented work which has redefined the role of the prototype in the design process. To provide better understanding of the term, further analysis is presented in four segments which form the core chapters of this paper: prototyping research method; iterative design process; reference to known prototyping practice in architecture; and future role of computer-aided architectural design and manufacturing in prototyping-based research

3. Prototyping research method

Prototyping is one of the recognised study and research methods in design-related disciplines, and in this context it belongs to a specific way of modelling, not to be confused with making of architectural maquettes. The purpose of scientific models is to represent reality. In order to be able to inform, communicate and reflect on reality we must imagine, articulate and simulate within a model (Klaasen 2005). In this sense models may be made of words and numbers, and need not be necessarily spatial as often understood by architects. There are different models in use and there could be a basic distinction between two different kinds: predictive and descriptive. Prototyping is unique in that aspect, as it includes both ex ante evaluation or prediction and ex post evaluation or description (Van der Voordt 2005). After construction, *ex post* research of the prototype may give rise to improvements and *ex ante* research that may lead to design adaptations or to the conclusion that design is ready to be built. Full cycle of study thus consists of building, testing and reformulating the design. The process may be of sequential order, with any number of such cycles. Also, design alternatives may be tested simultaneously and relation between *ex ante* and *ex post* evaluation may become less apparent.

4. Prototype in the iterative design process

Purpose of any prototype is to acquire knowledge which will be solely used for the construction of the subsequent model in the chain of iterations. Prototypical design process will repeat itself in an iterative fashion through several generations until the optimal solution is met. Instead of one and finite solution to the design problem, iteration sequence is a process of adaptation with a visible structure. This approach can be deployed in various disciplines: for example, iterative development is also a form of software development methodology: it starts with an initial planning and ends with deployment with the cyclic interactions inbetween (Larman and Basili 2003).

In architectural realm, the idea may be traced back to sixties and Christopher Alexander's research into the analytical nature of the design process which he contrasted with pure intuition and willful form making (Alexander 1964). His assertion was that design process for its complexity needs a certain structure whereby architectural form undergoes course of "gradual adaptation". Christopher Alexander's thesis was published in the book "Notes on the Synthesis of Form" (1964), in which an inspiring parallel between the process of biological adaptation and the process of design was drawn. He was interested in the relation between the form and its physical context and was an early design theorist to point out toward the work of Scottish zoologist, D'Arcy Thompson (1959) who at the turn of the century has explained changing anatomies of living organism under the influence of environmental forces. His remark that equaled form to a diagram of forces is heavily quoted by architects till today. When translated to architectural terms, this biological paradigm offered a fertile ground for new ideas on spatial form. In design world, Thompson's study "On Growth and Form" connected to the idea of the changing form and its multiple iterations according to appropriate performance related criteria such as construction method or use pattern.

Consequently and with the advance of computer-aided architectural design systems a specific ways of working in design oriented practices started to emerge, encompassing production of series of solutions prior to committing to the ultimate one. Today, a number of software packages deliver ready-made solutions for iterative design procedures via parametric control of geometric constructs with interrelated entities. A designer can more easily produce a number of digital simulations, each to be evaluated under specific criteria and in turn provide information for the next and more developed version of the design. Other designers develop custom tools reliant on scripting techniques and use of computer languages to establish and control iterative structure of the design processes. In both cases, greater investment is needed at the outset of such design process, with time and skill required to write a code or set parametric connections between the elements of the geometric model.

The economy of iterative concept is simple. After initial investment, design process may take iterative discourse to exploit certain idea development through a series of models along the continuous line of investigation. Benefits rest in more robust results, better development of the idea and more comprehension of the initial design problem. More trials there are the better will be the result. It is a methodological shift from one to many; from a single form to a series of forms each developed with its own specificities but also related to the one preceding its development. However there is nothing to suggest that standardisation and repetition are obligatory consequence of iterative development. It would be more correct to conclude that throughout iterative development only key aspects of architectural form stay constant, while others evolve to fit different needs.

This way, a designer anticipates development of the original idea through series of leaps which all generate data to foster the advance of the design. Such information may not be obvious and may make profound and unexpected turn in the design process. Moreover, it may help develop solutions dependant on testing as they may not belong to any known architectural typology. Iterative design sequence contains generative capacity. It is a way in which architecture can change to develop new and more agile ways of working to produce spatial organisations in response to changes taking place in new forms of social, cultural and economic institutions. Transparency of the iterative design process opens up the possibility of interdisciplinary and participatory development of the design process itself, allowing professionals from different fields and even end-users to take part in the decision-making process.

5. Prototyping practice in architecture

The idea of a prototype is not a new one. In industrial design, prototyping is a very common way of product development through testing of alternatives solutions. Prototypes are evaluated according to certain performance aspects or used to gain information from their interaction with users. Sometimes they serve the sole purpose of advertisement. In architecture too prototyping has been known for some time but in-spite of its obvious usefulness, it has been scarcely used. Predominantly, it is employed for the design of buildings which will be produced in large series of possibly identical structures, and will be able to justify initial investment in the construction of prototypical projects. This concept is literally borrowed from the industrial design, where the idea of the prototype originates from, and where it is more common to produce items in large series.

Van der Voordt (2005) makes note of several initiatives taken in 60s in the US and Netherlands to test and improve design for healthcare and correctional facilities. In all cases actual variants of buildings with different layouts were erected and then investigated according to occupancy scenarios, efficiency, running costs, energy consumption, safety and subjective perceptions of its users. Variant solutions were compared to one another in terms of the cost and quality. In addition to observation and measurement of quantifiable information, post occupancy evaluation included a set of questionnaires completed by several hundreds of staff members. Together this has provided data based evidence to be used for the development of the new model. In the long term, such study may suggest more initial investment that can be gained back in number of years or it may result in knowledge that can be directly applied to more economic construction of a number of following projects.

More often it is not feasible to build for the purpose of testing. While in industrial design prototypes are often made in real-scale and with the use of the actual materials, in architecture this is harder as building projects are significantly bigger and more complex. Therefore concept of prototyping if often downgraded to more viable ways of working. Change of scale could be the most obvious compromise to be made, but it would also bring the idea closer to the role of a large maquette that could provide only limited findings about spatial organisation or materialisation. Another plausible solution is to build a segment of the overall design on-site as a mock-up test to investigate behaviour of unconventional building materials or examine technical solutions such as facade joints. Nevertheless, mock-up tests do not generate other valuable information concerning overall structure. Similarly, construction of buildings with large number of similar of identical units, such as housing projects or hotels, occasionally include production of one such unit in real scale prior to the construction of the project for no other purpose but to act as advertisement showcase. All of the above named solutions provide only partial answers. While their value is not questionable, their purpose is directed toward certain aspects of architectural project and their correspondence to entire architectural undertaking is never absolute. Fidelity of any representational model is proportional to the quality of information generated through its testing and thus directly related to its purpose in the design process.

6. Future role of computer-aided architectural design in prototyping-based research

In contrast to previously described use of prototyping within architectural practice, this paper identifies another emerging area within the same field, based upon production of self-sufficient and autonomous prototypes, made without scale and with no utilitarian reason. Their purpose is to gain knowledge, to help develop architectural ideas and to put to test "re-emerging relationship between architecture and construction" (Kolarevic 2008, p. 151). Prototypes are highly unique when compared to the other architectural tools, such as digital models, maquettes or drawings. They are the only instrument in the hands of the architects that deals directly with questions of materiality. Prototyping exercise involves fabrication choices and construction strategies in parallel with the formation of the design intent, thus prompting unified thinking about conceptual and material aspects of the design process.

On one side prototypes are instrumental to exploring possibilities of current digital processes and their prospects with the role in establishing new design procedures and fabrication techniques. On the other hand, they are highly dependent on the development of computer-aided architectural design and manufacturing systems. For some time now, the potentials of current digital tools hold a key to more efficient structure of the design process. The demanding nature of iterative development and prototyping seeks investment of both time and finance, and its future is dependent on the development of more economic ways of working.

Computer-aided architectural design systems and building information modelling solutions are supporting a growing tendency to substitute physical prototypes with more effective digital simulations as modelling techniques are developing precision and more importantly the ability to capture material properties along with the geometric ones. In automotive industry, simulation models are already deeply integrated into the iterative process of prototypical development. In the well known case of the Boeing 787 Dreamliner, the first full-sized physical realisation was made on the series production line. In architecture, this is more difficult for a number of reasons. One of them is related to the link between computer-aided architectural design and manufacturing systems that is still much more developed in automotive industry. Arguably the easiest and the quickest route from digital to material in architecture is via "rapid prototyping" solutions, most often based on additive manufacturing technique whereby form is created from a great number of very thin layers of material. Also known as 3D printing, this process offers almost instant solution for an early insight into the physical form. However, very often it has little to do with actual fabrication process and might be even misleading to the actual design intent. Preparations for 3D printing have very little in common with actual fabrication strategy regardless of the fact that it will produce a true physical representation. Moreover, capabilities of the rapid prototyping machine will limit the choice of materials and design options. In that context both digital simulations and 3D printing present important aid in iterative design process but cannot be taken as the replacement for actual construction of prototypes.

In conclusion, the role of computer-aided architectural design is seen as fundamental in the development and further improvement of the iterative design process through faster and more affordable construction of prototypes. Introductory analysis of THEVERYMANY works presented here, show an example of architect's engagement with both design and building process, and the establishment of a new form of research oriented practice based on the production of prototypes. The challenge we can identify here is in further integration between digital processes of design and fabrication, along with the creative combination of digital and analogue modes of working. Here we speculate that the “prototypical architecture” is the right testing polygon for this. Having analysed the theoretical approach in this paper, further research will involve practical case-studies of the applications of the prototype-based iterative architectural design process. Finally, in direct relation to CAADRIA2012 sub-title, the work described here suggests that the route from “bricks and mortar” to “nuts and bolts” and on to “codes and pixels” could unfold in a non-linear fashion and active interchange between digital and physical domains.

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