Towards a dialogical design of future cities

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Abstract. This paper presents an experiment on an open source construction system named Woka, which allows anyone to design and produce dwellings using standard CNC techniques. Woka was developed as a dialogical design process that empowers self-builders to act in a more autonomous way, expanding the traditional role of design practice and the way buildings are created. The advent and popularization of new design and fabrication processes have encouraged a flux of new theories and project strategies based on computing, each with its promise of changing the architectural practice. Some of these resulted in intellectually seductive; visually provocative and complex shaped architectures, generating a new formal repertoire, but doesn’t indicate a paradigm shift in the process of production of architectural space, still based on authorship. Woka challenges this traditional process proposing dialogue as a design approach, shifting the focus from the object to intersubjectivity, amplifying the potential for novelty to arise.

Keywords: Parametric design, digital fabrication, dialogical design, autonomous building

1 Introduction

The name Woka derives from the wiki (open to) and oca (indigenous house or dwelling). It is an open construction system that updates the building tradition of indigenous people where residents design and build their own homes. Based on a DIY (Do it Yourself) logic, it is a process that allows anyone to design, download, print, build and complete their house or components. Woka explores the integration between Wikihouse, Sketchup (dynamic components) and Bimbon as an interface that mediates the design and building process of the house. Woka explores the potential of parametric design to involve the user in the design process. In traditional design processes – that use CAD programs as an extension of the drawing board – the change of parameters, like the geometry of a room, could only be implemented by suppression and reconstruction. This is rethought in a parametric process, where the model can be defined as a set of geometric relationships that are applied through
parametric expressions and constraints. This chain of geometrical relations can be manipulated without losing the consistency of the hole. If these parameters can be manipulated in a dynamic form this opens the possibility to involve the user in the design process.

It is because the digital representation is constructed with codes and algorithms that can be read by numerically controlled machines, that the information embedded in the drawings can be directly materialized by CNC laser cutters, CNC milling, 3D printing etc. This ability to generate constructive information directly from the drawings information is one of the most relevant aspects in contemporary architecture. This direct connection between design and fabrication is already a common process in automotive, aerospace and shipbuilding industries. However, it was only in the last decades that the advances in computer aided design (CAD) and computer aided manufacturing (CAM) has caused more impact in architectural production.

The possibility to alter parameters in real time in architectural representation already existed at the first stages of development of digital design technologies. Ivan Sutherland Sketchpad System for example enabled the user to change the drawing without breaking the chain of geometrical relationships. This was later further developed in software like Radar CH, created in Budapest by Gábor Bojár in 1982, latter known as ArchiCAD and the first BIM software made available on a personal computer, or REVIT, one of the most popular BIM software that was conceived by Parametric Technology Corporation (PTC) and later purchased by Autodesk. Although these software’s made important advances they were built based on standard building workflows and normally don’t leave much space to different approaches to design. Most software developers were more focused on the improvement in productivity and the automation of tedious and repetitive tasks, then to enable the user to participate in the design and construction process. But recently with the popularization of digital fabrication technologies a pleura of design proposals based on digital design interfaces for architectural production emerged that enable a different and more open approach to design and fabrication. Woka is an experiment that associates a doctoral research and a broader investigation of digital fabrication both working towards this goal.

This paper presents an ongoing research about Woka and is organized in the following manner: first we will present the motivations that triggered our investigations and experiments; second we will argue about the research methodology and some similar cases that laid the base for the design process; third we will present the initial prototype and its evaluation; finally we will discuss about the findings and make our conclusion.

1.1 Motivation

For long architects have made claims that the general public should give more value to their work and recognize their importance. That is not different in Brazil, where architectural organizations have been battling to get people to hire architects to design their buildings. This is a strange fact if confronted with the numbers of the federal government that estimates that the housing shortage is of about 7 to 10 millions of
homes. If there is a lot of work why are the architects not involved? So the question is not only how to instruct the users about the importance of the architect, but more important, how do involve architects in the actual construction of the build environment. The Brazilian government is filling this gap left by architects by building thousands of mass production houses creating entire new neighborhoods of standard houses through the federal housing plan *Minha Casa Minha Vida*. To solve the huge housing shortage by building standard cities is highly questionable and to hinder this architects need to think about different ways they can participate in the process. To have architects to design each house in dialogue with the future inhabitant could be an answer, but design is an expensive commodity that only a few can afford. Other strategies are needed to confront this problem.

Alejandro Aravena Elemental houses in Iquique shows a different approach to this problem by enabling some level participation of the user in the design process. Elemental is a profit company with social interest focused on developing social projects. The houses in Iquique are the first experiments on a house typology that involve the user in the construction process. The design of the building leaves a structured open space where people can later continue to build their homes and adapt it to their needs. It is an interesting approach since it enables to optimize the use of public or private investments by building a basic unit that can later be expanded by the user. The money can be directed to buy the land that is normally expensive nearby urban infrastructure, leaving the expansion of the house to the user. The problem with such approach is that people may need to hire another architect to finish the building, or build it without any support. It is true that people have been building without technical support for centuries without much problem, but other strategies may be of interest.
John Habraken proposes one interesting approach to this problem. Habraken [1] developed the potential of customization of open structures and created the concept of support (drager) and infill, in a process called Open Building. The support is socially created as a tri-dimensional urban planning and the infill can be individually developed. An important aspect of Habrakens work is the shift from object to process, as for him the most important was how people would participate in the design process. The Open Building concept reveals that parametric design and digital fabrication still has a vast field to be explored. Open Building was not conceived as a digital tool, on the contrary, it is a series of principles and approaches to architecture regarding different issues and discuss a pleura of questions that the research in digital fabrication processes are trying to cope with.

The key point in the Open Building approach lies precisely on assigning responsibility to the user, who participates in the architecture design process according to some principles that insert him into the specific context in which inhabits. The digitization of architectural design processes ensures greater accessibility to those all involved in the process, from the designer to the user. Thus, a more concerned approach to user relationships with the architectural design process, as in the Open Building, can be even richer in the context of digital fabrication, which facilitates the distance of a more formalistic approach that reduces the number of specific issues currently dwell in cities. Woka was proposed as a design alternative to explore this potential of involving the user in the design and building process.

1.2 Methodology and similar cases

The methodology proposed for this research is based on the association of theory and practice in a heuristical process of investigation. Studies that deal with the use of new
digital tools and technological devices in architecture represent a challenge, because they generally deal with *wicked problems*. *Wicked problems* is a concept generalized in design by Buchanan [2] that designates problems that are hard to formulate, where information is confused, the agents involved have conflicting values and the ramifications of the system are dubious. Architecture deals with *wicked problems* because it is contingent, it is constituted by complex and contradictory relationships continually open to uncertainty. As augmented by Till [3] architecture can’t be resumed to one idea or concept that can be research and dissected through traditional scientific methods based on causality. Therefore what is presented in this paper is not a finished product, but an open and continuous investigation that is informed by cycles of design, prototyping and evaluation. The initial prototypes and its evaluation will be presented in the next section, but first we will present and discuss some similar cases that laid the base of the design process.

It can be noticed that a pleura of design proposals based on the popularization of digital interfaces for architectural production recently emerged. Generally they intend to present a digital interface associated with a relatively friendly design that tries to give people access to different digital fabrication processes. Most operate using CNC milling or laser cutter machines to fabricate joints and sections that can be easily assembled. One of the most widespread interfaces is *Wikihouse*[4]. This process, proposed by the English architects Al Alastair Parvin and Nick Ierodiaconou, has as main characteristics the use of the *SketchUp*[5] software, the definition of design principles and the creation of a shared database. The first design principles define which type of wood is to be used, how to think about the fitting of different elements and its resistance. These principles also cover how one should draw the elements in *SketchUp*, which is relevant for the *Wikihouse*, because it uses a plugin designed for this software. This plugin is presented as one of the great advances of the system, as well as one of its advantages. In this manner, *Wikihouse* is not specifically a house, but an integrated set of processes that enables people to produce an architectural artifact.
The plug-in developed for Wikihouse generates the cutting diagrams, that is, it transforms the 3D model into a file with bidimensional drawings of the pieces that can be read by a CNC cutting machine. This is the automation of a relatively complex task that is executed with one command in the program. As this is an application designed under the Creative Commons license, the Wikihouse encourages sharing of the designs produced with the same logic with other users through the online database. The database is constantly updated and enables an exchange of experiences between different users in several parts of the world such as New Zealand, Brazil and Holland, among other countries. Each of these centers have developed an autonomous and different approach to Wikihouse in their specific contexts, which has resulted in very different experiences.

Besides Wikihouse, we can identify other proposals that have similar principles and approaches, with some differences of nuance. Click Raft[6], Hermitt Houses[7] are some examples that have a similar description with Wikihouse and have very similar results. The American architect Greg Lynn, famous for his experimental approach to digital representation technologies and digital fabrication in architecture, also proposes a parametric process for developing a housing system using similar strategies. The project for the Embryologic Houses was an attempt to explore the process of parametric design and digital fabrication to generate a series of customizable houses in different shapes departing from the same design logic. The design enables some level of openness as the geometry can be modified within the predefined parameters of the components maintaining the same structural logic. This process facilitates the customization of different units as all the parameters can be easily manipulated by the architect, but it doesn't involve the user in the design process. On the other hand, one example of interface that enables a higher level of user participation in the design process is Sketchchair[8].
Sketchchair is an open source software developed to facilitate the design of chairs intended for digital fabrication. The system enables the user to control in a simple manner the whole process of design of a chair, including initial drawings, detailing, testing and manufacturing. The interface consists basically in a 2D work plan with drawing and editing tools. The whole process is based on the manufacturing method with ribs, generally called waffle, where the object is sectioned in the longitudinal and transversal directions forming interlocking planes. The user can easily draw the profile of the chair and latter adjust the layers and sections to determine the final shape. The software also includes a system that enables to test the ergonomy and to simulate gravitational forces. The ergonomy test is done with a figure that represents the human body and can adopt different measures. To test the proportions of the object the software dispose of several reference images like tables, other chairs etc. The product is a vector file with all the pieces of the chair that can be sent to a CNC cutting machine or even printed as a mold and cut by hand.
In terms of the discussion on the possible relationship between the principles of digital fabrication and architecture we can say that such systems represent significant progress. However, they still have several limitations that represent a few challenges. Although we do not see a system that has reached a full and mature result, that is, which has succeeded in producing large-scale architectures and with the level of diversity initially proposed. Most systems generate products with the same aspect and are generally unfinished. We believe that one of the reasons that gave prominence to Wikihouse is the fact that it is an open system for collaboration, leveraging different dialogues and experiences. Also, because of its choice of software that gave support to the system as SketchUp has a simple and friendly interface design and has become one of the most popular 3D modeling software in the world. The Wikihouse app aims to facilitate a relatively complex task in a very simple software. However, this task is not yet fully developed because it still has many limitations. In addition, to the application to be efficient in practice, it demands a very complex modeling to generate all the necessary parts, which makes the process slower and subject to numerous imperfections. The houses developed with Wikihouse look very similar to each other, which leaves some doubts about the degree of openness of the design process. Perhaps even unconsciously, the architect Greg Lynn used this deficiency as a positive fact, because the houses he proposed were different to each other, but all had the appearance of a design produced by him, which for many represents a brand value in the product.

![Embryologic Houses by Greg Lynn](image)

Besides the used marketing strategy, the fact is that for open systems and supposedly, largely parameterized, the similar results show a low diversity, which it could mean a low degree of openness to one who uses it. This means that these systems could be promoting a poor dialogue or no dialogue between those involved.
The design principles end up becoming more a formal rule than a coherent set of parameters that facilitates the architectural design.

Another aspect that should be highlighted is that most systems only include the use of new materials such as plywood, failing to consider the use of existing materials available on the context of use. Of course this is a task that would make this systems even more complex, however it enables a more sophisticated approach to the existing contexts, generating more specific and less generic solutions for each design problem. These systems still don't explore the potential of the use of modular coordination principles. The fact that they are parametric, or present ability to be, facilitates the task of carrying out this type of coordination. The more this coordination relating to the use of existing materials, the more such systems opens to diversity, abandoning the emphasis on aspects often purely formal. This is not a simple task, but the rise of digital fabrication tools and the share of information through open source communities permits us to operate this complexity, empowering more individuals to deal with it. In this way such interfaces open to different possibilities for dialogue, which extends the range of solutions.

If we compare the Wikihouse to other systems such as Click Raft and Hermitt House we see that another subtle difference expands its potential use. The Wikihouse defines some principles of design while the others already define a shape. Although most of the principles of Wikihouse are essentially formal, there is a minimal concern in the user input in the design process, which opens a possibility for dialogue. At the same time it reveals how parametric systems have enormous potential to trigger dialogues, especially if their basic assumptions include the user's as co-responsible for the production of architecture. In this sense, digital interfaces for architecture show greater potential for dialogue and, consequently, increase the variety of solutions, if they are more based on principles that enable the individual intervention of those who inhabit those spaces, giving them the tools to act.

In this sense, Woka avoids the use of the Wikihouse plug-in because of its problematic aspects and seeks to develop some procedures to optimize the 3D modeling tools. The interface in Sketchup was built on dynamic components with simple commands, like stretching, clicking and scaling. The most important feature is to leave a level of openness to the user to choose different materials and configurations. This openness allows the creation of a variety of different outcomes. The next section will explain in more detail how this process works by discussing the first prototypes.

1.3 Woka 0.1 – First prototype

Woka is not a finished house, but an open construction system based on parametric design and digital fabrication intended to trigger the design and building process. The idea is to generate a inner shell that is immediately deployable combined with a more durable outer layer that can be added later with conventional building systems available at the site. In that way people can create an initial proposal to respond to their immediate needs, change and adapt their design on site by reconfigure the parts and use their own building culture and collective knowledge to finish the
construction. In that way the systems enables the dweller to add his experience to the design based on his own culture and different ways of inhabiting. The Wikihouse concept was used to create a module that can be dynamically changed in Sketchup. A dynamic component was created that can be stretched in two directions and be combined to other different components. A plug-in called Bimbon[9] (www.bimbon.com.br) was used to automatically generate the building cost and material specification, so that with each modification of the original design the estimate cost is recalculated.

![Fig 7: Illustration of the process.](image)

An important change proposed to the Wikihouse system was to create a dynamic component drawn in Sketchup that consisted of the detailed drawing of the whole rib structure. We chose to use the detailed version to create a direct correspondence of the representation of the module with the elements that were going to be fabricated. Because the Wikihouse plug-in failed to create the right joints we abandoned it and used the design proposed by the New Zealand group Space Craft[10]. Since the structure proposed by Space Craft was already designed and calculated to resist earthquakes it was a reliable set to work with. The use of this dynamic component was of great importance to enable unskilled users to manipulate the drawings, since simple commands can alter the form and configuration of the house.

The fabrication process is based on a 3 axis CNC cutter (laser or router) and consists of a rib structure built from plywood sheathed with OSB panels. The product is immediately deployable, can be easily mounted, dismounted and transported. The possibility to customize the sections and joints and to fabricate it fast with high quality enables the inhabitant a different living experience as the modules can be used in diverse situations and possible scenarios. It can be used to build a house, an annex of an existing house or even a office or garden house. The polyvalent nature of the system and its low cost enables many solutions to take place and fits to reality of each one.
The first design consisted in a house with one sleeping room with balcony, one bathroom, one living room and a kitchen using in total five modules. It was chosen to keep the design as simple as possible to enable its construction and evaluation with a low budget. The roof joints were designed to facilitate the use of insulated metal roof tiles that also covered the facades, and also enabled the use of other materials. Part of the house was covered in glass to expose the rib structure because of the experimental nature of the first prototype. All the interior was coated with OSB panels, including the floor and ceilings. The final cost of the construction calculated with Bimbon was of $ 6000,00 dollars, which is still expensive for low cost housing in Brazil. What elevated the cost was the price of the CNC cutting of the plywood plates which is still very elevated. Because most of the machines available are used in an industrial context there are few that are willing to stop their production to enable this kind of project.
One section of the house was fabricated in a 1 to 25 scale to test how the joints worked in the actual material. The premise was that if the structure would work in a small scale it could have a similar effect in a 1 to 1 scale. The prototype proved easy to fabricate and assemble. Although this can't be said to be true in a 1 to 1 scale it seems that it will work likewise.
1.4 Discussion

Traditionally, most architects use processes based on prescriptive digital representation that allows little or no openness for user participation in the design and creation of the architectural space. When trying to control all design parameters in an attempt to predict possible errors, define situations and configure form, the architect may end up restricting the potential for a more creative architectural appropriation. In extremely complex systems such as architecture the number of states of the system is exponentially greater number of states that the architect is able to anticipate. Thus the only way for the architect to exercise control over the project is by restriction, since according to the Law of Requisite Variety [11], for a given system to control the other is necessary for the controlling system to have at least the same amount of states as the controlled system. Glanville [12] compares this type of control by restriction with dictatorial systems that work based on power relationship. In this context the architect operates by defining the form and by restricting the possibilities for more open appropriation and use. In contrast, Glanville [12] argues that to lose control can be a strategy to expand the number of options available allowing us to be more creative. To Baltazar [13] an alternative to break with control, restriction and limitation of the design is to think architecture as open process, establishing continuity between design and use. This openness can be reached by opening the design parameters to be manipulated by the user.

The opening of design parameters to interaction with the user can significantly increase the number of states of the system, expanding the number of options available. The method of producing architecture as well as the work of the architect is substantially modified. But unfortunately it does not happen in practice and architects, in contrast, face an ethical problem by restricting the increase of the number of possibilities to their practice in the office, not extending them to the end user [14]. In most cases the parameters are crystallized in final form, that remains closed and unchanging. This is aggravated by the transduction of the coordinates and vectors in physical matter on the basis of digital manufacturing processes. Shell [15] warns that this physical rendering of codes in finished products can skip an important step of the possible transformations of initial design during execution. In this sense Woka was designed to trigger a building process, and not as a finished product. The idea is to establish a continuous process of design, fabrication and use of the architectural space. This is possible because the system enables a fast assembly and disassembly of the constructive elements. People can easily rearrange the spatial configuration by changing some elements and by fabricating new elements and joints. This joints can be designed by the user or downloaded from an online database. In this way the parameters are open in the design and fabrication process. A limit in the opening of parameters was established so that the basic module can be immediately deployed, even if the outer shell is not rapidly finished. In this way the user will not essentially need another architect to finish the building.

Woka can be associated to the concept of open design that is defined by Paul Atkinson [16] as "the collaborative creation of artifacts by a dispersed group of otherwise unrelated individuals and of individualized production". This concept is
related to a movement where individuals collaborate to the creation of knowledge, objects, cultural production, services, etc, that has been given a great impulse since the popularization of the internet. Atkinson [16] notes two aspects that should be considered to make the open design technologies more acceptable to a wider public: the development of more user friendly interfaces with a more intuitive system for the creation of tridimensional models; the distribution of more appropriated materials for the use in digital fabrication machines. The role of the designer goes from the design of closed objects into the design of interfaces, or processes, to provide user with support to create their own design. Jos de Mul [17] calls this new process database design, where the designer doesn't design objects, but creates a drawing space where inexperienced users can access user-friendly interfaces within which they can draw their own objects. In this sense the designer creates a metadesign that only materializes as product through the interaction with the user. The creation of these metadesigns may represent a possible alternative to the increasing control exercised by architects in the design and construction process, made possible by the association between parametric modeling and digital fabrication.

The idea to create interfaces to enable unskilled users to access complex data is not new. In the early days of the computer it would be difficult to imagine that a computer would fit in a pocket and be used by almost everyone, regardless of education or age. What made this possible is a combination of factors where the interface plays a big role. A evidence is that computers are today several times more complex and faster than in the early days, but are much easier to use. In that sense, the creation of the dynamic component in Sketchup that allows the user to easily manipulate the design is of paramount importance. Although it may appear that parametric systems can be difficult to be manipulated by unskilled users, the questions lies not in the level of complexity of the system, but in the design of the interface.

Woka reinforces that the digital fabrication technologies, when approximated to architecture, open the possibility for the participation of the user in the conception of space, making him co-responsible for the design. Jones [18] also advocates the shift of the focus from product to process, since the goal of the design should not be the finished product with a particular function, but the very continuity of the design process. For Jones [18], in the process everyone is a designer. In this sense the focus on the process allows the user to transform into coauthor of the design of the architectural space, increasing its active role. In one level Woka inserts, even in a preliminary way, the user in the process, allowing him to take some key decisions for the realization of each project. But in a second level, the user may share his design experience in the database to participate in the cycles of iterations, blurring the distinctions between user and designer.

1.5 Findings

Woka was developed as a dialogical design process that empowers self-builders to act in a more autonomous way, expanding the traditional role of design practice and the way buildings are created. The way to produce architecture, as well as the work of the architect, are sensibly modified. The role of the designers shifts from the creation of
designs to metadesigns that only materialize through dialogue with the user. Our initial experience with Woka revealed that the creation of metadesigns is a complex task because of a list of reasons. First because of the need to create interfaces to enable people to access the design parameters. This interface have to be simple enough to be easily accessed by a non proficient user and as complete as possible to enable the manipulation of parameters. Second, by reason of the importance of the design principles over geometry and building form. It is important to enable a real participation of the user in the design process without constraining possible outcomes and use of different materials. Third, by virtue of the necessity to choose which parameters are left open to be manipulated by the user and which are not. Finally, as a result of the need to create or use an existing database to feed the different cycles of iterations and dialogues between different users and designers. Woka is a work in progress and by cause of its nature may never become a finished product. But the work already developed raised a series of important questions that advance the discussion about the use of parametric design and digital fabrication in architecture. In this way Woka challenges this traditional process by using dialogue as a design approach, shifting the focus from the object to intersubjectivity, amplifying the potential for novelty to arise.

Although some advances were made, there is a long road to reach a more sophisticated and complex metadesign that will empower people to create their environment. The next challenge in the process of development of the Woka system is to further investigate the possibility to associate the digital fabrication system with more common building materials, and to explore more intuitive interfaces for design.

Acknowledgements

The authors gratefully acknowledge the financial support given by CAPES ad NPJAU da UFGM.

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