

## THINKING ABOUT SYSTEMS

*Collaboration aspects and local context in the design process based on parametric design and digital fabrication*

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**Abstract.** This paper presents the organization of a design process which allows the inclusion of communities in a collaborative way and integrates cultural and social aspects of local context, by considering available material resources and equipment, local practices in architecture and construction, environmental features, and other aspects into the possibilities provided by parametric design and digital fabrication. This paper recognizes that design process is developed from interrelated actions, which can be understood by the concept of complexity from the French philosopher Edgar Morin.

**Keywords.** Complexity; Design process; Parametric design; Digital fabrication.

### 1. Introduction

Several references and experiences seek to explain how digital technologies have changed practices in architecture by introducing new possibilities for spaces conceived with complex geometries and their visualization and simulation. For instance, Woodbury (2010) presents how architects and designers must deal with algorithmic thinking by changing their mental processes through digital technologies. Kolarevic (2009), Iwamoto (2009) emphasize aspects of introducing digital technologies in design process, focusing on digital fabrication possibilities.

The literature on parametric design and digital fabrication certainly points to important aspects of several issues in architecture practice. We seek to contribute to this discussion by focusing on an approach that integrates collaboration aspects into the design process based on parametric design and digital fabrication. However, in this paper, we are not considering the collaboration aspects such as the range of professionals working in a collaborative way in the design process. Certainly, this sort of collaboration occurs and it is part of the design process in architecture of any nature. We are hereby concerned about another aspect of collaboration, that which integrates community participation into design conception, and how to bring this community into the design process based on parametric design and digital fabrication.

This paper analyzes collaboration in the design process through a research activity carried out as part of a major project called Hybrid Territories conducted by Nomads.usp – Center for Interactive Living Studies, a research group from University of Sao Paulo, and funded by Fapesp – Sao Paulo Research Foundation. Hybrid Territories is a public policies project whose objective is to promote dialogues among different realities and social contexts by constituting hybrid spatialities, i.e., by combining physical and virtual instances. The project seeks to explore the idea of tolerance, diversity, and co-existence, and to expand people's worldviews.

To this end, the research activity, according to the project purposes, aimed to bring together people from different groups - public housing complex residents, students and professors from architecture schools, local industry, cultural agents, and public government - to discuss public spaces and cultural activities (Nojimoto, Soares, Ventura and Tramontano, 2013). The research activity was organized with the intent of developing and producing a pavilion to be assembled in a public housing complex to house cultural activities. In this paper, we focus on residents' collaboration during the design process based in parametric design and digital fabrication.

Another important aspect in this research activity, also analyzed in this paper, is its consideration of local context, e.g., site, local construction practices, available material resources, and other aspects inherent to the public housing complex and the urban context in question, a 200,000 inhabitant Brazilian city located near major cities in Sao Paulo State. Considering local conditions is certainly a prerequisite to any project, but in this activity, to consider local conditions also means a strategy to stimulate public housing complex residents to collaborate in the design process. It did not imply that the pavilion would follow the most usual construction system in this specific cultural context. The objective was to create a pavilion for cultural activities exploring complex geometries by using specific computational programmes

and at the same time using construction techniques and materials easily recognizable by local community and other participants in the design process. By local context, we also mean the range of professionals, local industry, and material suppliers available in the city.

This paper acknowledges that the design process is developed from inter-related actions as understood in the concept of system and complexity from the French philosopher Edgar Morin (2005). Therefore, the collaboration and local context aspects can be analyzed from this systemic and complex perspective. Morin, based on cybernetics and general systems theories, developed an epistemological approach focused on understanding the object of observation from a broad perspective that goes beyond the Reductionist methods of inquiry, which breaks down the object into pieces in order to understand it. This complex thinking approach sees the object or the phenomenon of inquiry as something more than the sum of its parts, thus, it cannot be understood in its entirety unless considered as a system. This approach helps us to analyze the research activity and, as a result, the design process in light of many aspects especially those related to collaborations and local context.

According to Morin (2005), we must consider objects and phenomena as systems whose elements are in constant interaction, which he calls interrelation. Morin (2005) also explains that interrelation refers to types and modes of connections among elements or individuals, but the presence of connections are not enough to make a system complex. It is also necessary to consider how elements or individuals are organized inside the system and in relation to the whole. From the interrelations comes the organization that connects, maintains, and transforms the system (Morin, 2005). Then, for a system to become complex, it must feature organization and interrelation.

As to organizations, it is also necessary to mention the concept of system openness, a feature that allows exchanges with the environment. It means that the system can reform itself incessantly (Morin, 2005) by exchanges between what is inside the system and what is external to the system. According to Morin (2005), in this process, the system organization is responsible for preventing the system from spilling to the environment or the environment from invading the system. This concept helps us to understand how external inputs can promote changes in the system.

Morin's thinking on systems and complexity is an approach that allows us to understand and analyse several aspects of research activity. By taking into account a research activity that embraces different elements, local context, and all sorts of situations that occurred during the activity, this approach seeks to include this range of aspects.

## 2. Cultural activities in design process

One of the biggest challenges in planning the activity was to develop strategies to get people to collaborate in the design process, not only from communities, but also from industry, universities, public governments, and cultural agents. Everyone participates in the design process in different ways and stages carefully planned previously. However, this paper focuses on the collaboration of residents of a public housing complex and the strategies adopted to encourage them to contribute to design process.

One strategy adopted was to include cultural events that would occur during the entire research activity, from the conception of pavilion to its assembly at 1:1 scale. It intended to engage different groups of residents in the process so as to investigate a wide range of aspects and opinions on public spaces for cultural activities. Previous activities performed there provided us with some information on their opinions on public spaces. However, this information was provided by just a few groups from the housing complex whereas this activity should have been able to encompass different points of view, from other groups as well.

The first activity planned was to begin a conversation on public spaces for cultural activities with all residents by means of letters left under the door of each housing complex unit. The letter introduced the idea of assembling a pavilion for cultural activities within their housing complex and we requested their opinion about the kind of events they expected to be held there. We also requested their opinion about the place where to assemble it. Several suggestion boxes were installed in the housing complex in order to encourage them to place their opinions. We also encouraged people to express their ideas through Facebook, email, telephone or by going to the university.

After this first activity, the purpose was to alternate between cultural events that promote residents collaboration and design workshops involving students, professors, professionals, and local industry to solve technical aspects of the pavilion project. The cultural events aimed to show the residents all stages of the pavilion design process and encourage them, however limited by some constraints, to collaborate way in the development of the pavilion. Therefore, the goal of the first cultural event was to make residents aware of public spaces available in the housing complex and to introduce the first ideas for the pavilion. We showed them several pavilions that used parametric design and digital fabrication to create complex geometries but whose construction techniques did not necessarily require huge construction equipment. Moreover, the pavilions shown were built with materials that could be easily found in their local context such as wood, metal sheets, and cardboards. The event also introduced the possibility of creating spaces that

differ from those they are used to seeing in their everyday lives, thus attempting to call their attention to other types of spatial qualities, including those generated by complex geometries.

To achieve the goals set for first cultural event, researchers planned activities such as kite-making, photography, physical expression, and tree-planting workshops aimed at establishing relationships between residents and the space where they live. The photography workshop, for instance, promoted different perspectives on the space by taking pictures of it. The kite and physical expression workshop stimulated other uses for the space and the tree-planting workshop aimed at changing the space. These workshops were carried out with the help of cultural agents thereby connecting the residents to others participants in the research activity.

We also developed a Grasshopper script to present possibilities of complex geometries. The residents were able to control the pavilion script so as to make changes in the digital model and to visualize these changes (Figure 1 and Figure 2). The purpose of encouraging residents to operate the software was to show them that the changes they promoted in the digital model could be recognized later in the pavilion built. By operating the Grasshopper software users can visualize their own changes by in a digital model. Then, a connection between the residents and the physical space was established by their engagement in spatial changes, even though the Grasshopper script and the digital model produced during the event was not in fact the same used in the next stages of the design process.



*Figure 1. Residents of the housing complex during cultural event. Figure 2. Digital model of pavilion developed by residents.*

The next set of activities comprised design workshops with architecture students, researchers, professors in association with universities and local industry. The workshop was divided into two stages: (1) conception and partial prototyping of pavilion and (2) manufacture of pavilion components and its assembly. Following the strategy adopted in this research activity, there should have been the alternation between cultural events and design work-

shops. After the first stage of the design process, a second cultural event should have occurred in which researchers would present small-scale pavilion models. During the event, which should have been associated with other cultural activities, residents would be able to see physical models and check out construction techniques and the assembly possibilities. They also would continue to explore the Grasshopper script to produce their own physical models by means of a laser cutter, which would be available in the event. This cultural event would be the extension of the process started in the first cultural activity by keeping up their interest in the pavilion design process and at the same time suggesting some changes or asking the group of students and architects about several issues that they considered relevant.

After the second cultural event, the design workshop would be focused on reviewing some aspects of the pavilion according to what had been discussed with residents. At this stage, sections of the pavilion would be built to test some construction techniques and its components manufactured digitally. The assembly would be done *in loco* during a third cultural event in which people would be required to collaborate again, but now to build the pavilion in the physical space.

However, the second and third cultural events did not take place. The alternation planned between cultural events and design workshops did not occur as expected. After the first cultural event, only the design workshops were conducted due to external factors that demanded a thorough review of the activity. Then, during the design workshops, researchers, architecture students, professionals, and professors developed the pavilion project and prototyped it partially at 1:1 scale (Figure 3) based on parametric design and digital fabrication. Supplied with different kinds of information from the local context and data collected at the first cultural event and in the other aforementioned activities adopted to engage the community, the design team used the Grasshopper software to explore possible shapes and to produce the pavilion components.

Developing the pavilion by means of Grasshopper allows the team to explore several aesthetical possibilities in view of producing a complex surface that differs from the architectural context of the housing complex in question while at the same time seeking to employ low-cost and easy-to-find construction materials. After completing the Grasshopper script, several models were developed and presented to the whole team since each teammate was engaged in solving different problems during the workshops. The production of the digital and physical models informed participants during discussions so that decisions could be readily made.

Although the cultural events and workshops could not be performed as expected, the pavilion development continued in work sessions, not as pre-

viously planned and carried out in a way that differed from that of the workshop sessions. The work sessions were planned to be conducted in shorts sessions lasting longer than the workshops. The focus was mainly to solve problems in the Grasshopper script and the structural behaviour. No cultural events with community participation were held during these work sessions. The team of researchers, architecture students, and professors, with the collaboration of local industry, engaged only in producing the 1:2-scale pavilion prototype (Figure 4) in order to verify its assemblage and material and structural behaviour.



Figure 3. Pavilion being partially assembled.



Figure 4. 1:2-scale pavilion prototype.

### 3. On collaboration aspects and local context: thinking about systems

The design process and the whole research activity can be considered, from Morin's perspective, as a complex system, in which everyone is as an active element in interactions within the system and related to the system as a whole and how these elements are organized. In addition, all movements and actions of these elements within the system promote changes in the whole. In the case of the research activity, we are assuming as elements of the system people who collaborate in the research activity, including community, students, professors, professional, industry, cultural agents, researchers, material suppliers and government.

According to Morin (2005), we can consider the residents of the housing complex as one of the elements of the system and their presence as well as their actions and interrelations with others promote changes in the whole system. Although it was not performed as expected due to changes in the design process and research activity, interaction among residents and other collaborators within the system occurred mainly among residents, students, researchers, and cultural agents (during the first cultural event promoted). Therefore, there was an intensification of interactions and, in spite of not happening among all collaborators, these interactions became stronger at

least in relation to researchers, which gave rise to later partnerships in other contexts.

Collaboration can also occur among residents themselves in order to promote real changes in physical space. As systems are part of other systems, it is possible to imagine that another system can emerge from the one created during the design process, a system whose elements are the residents themselves organized to discuss and promote changes in the space they live. As evidence of this possibility, we noticed that the residents of housing complex started to tend for trees planted during the cultural event and another cultural event was promoted in the area where the pavilion would be assembled.

Digital media played an important role in the system. They intensified system connections by allowing information to flow throughout the whole system. They make information available to everyone by means of simulations, graphical representations, 3D models (digital or physical ones), spreadsheets. Engagement is collaborative when everybody in the design process is aware of their contributions, roles, and openness to share and analyzing information provided by others. Thus, digital media can bring people closer together and become more engaged in one activity.

Parametric design and digital fabrication played an important role in processing the information provided by one of the elements of the system and transforming it into another type of information, available to other collaborators. By promoting information flow throughout the system, elements not connected before can start to communicate to one another or can strengthen the communication established before. Moreover, they can promote direct and fast connections among collaborators, e.g., the connection between students and researchers with the company that produced the pavilion components. As to the housing complex residents, parametric design and digital fabrication generate representations and simulations, which in turn promote space visualization before its materialization. Through this possibility of visualizing and changing the space in a digital model and after that in a physical model, parametric design and digital fabrication processes helped to intensify connections among the residents, students, architects, professors, and researchers. These connections are also important to promoting the process of self-recognition as belonging to the system. With respect to communities, these connections should clearly show that their actions and the information produced by them are really promoting changes in system.

The system environment is also important to system organization. It provides all sort of inputs that can make the elements interact with one another thereby promoting a rearrangement in the system. This is a feature of open systems, which means that they perform exchanges with the environment. Thus, information about the public housing complex, residents' everyday



lives, community's cultural aspects, city's economical and cultural context, and local resources are a few examples of inputs provided by environment to design process. Environmental inputs should not be overlooked in a system. It is necessary to acknowledge the presence of these inputs and that they can change the organization of a system.

This assertion can be easily accepted when inputs are known and expected. However, they are not so predictable and obvious. The system openness suggests the inclusion of the unpredictable and not determined (Nojimoto, Soares, Ventura and Tramontano, 2013). Non-predictable inputs can come from the environment at any time and can be of any nature. In a design process, accepting external and non-predictable inputs changing the system can be difficult, but they must be taken into account, since the design process will be susceptible to environmental inputs in an open system. In the case of the design process performed in this research activity, environmental inputs were initially considered, such as those deriving from the local context.

However, unpredictable inputs promoted changes in the whole system and rearranged what was had been planned. After the effort to consider the local context in order to promote community collaboration in the design process, the fact that the pavilion was not completely assembled on the site could have been disappointing. However, considering the design process as part of a system that was rearranged due to external inputs, it was successful since it intensified interaction among elements, including the community. These connections among all elements in the system mean that a network was established. Despite the pavilion not having been assembled on the site, the network can stimulate further partnerships, which, in fact, happened afterwards when researchers and students in collaboration with local industry developed a 1:2-scale pavilion prototype.

We can view these further partnerships as an emergent feature of the system, understanding emergence as new qualities of systems that come from the organization of elements in interaction. Emergence is an outcome of system organization (Morin, 2005). However, these features differ from the qualities and states of the elements or the previous system. Moreover, further partnership is one possibility of emergence, other types of emergence can also occur, depending on interrelations among collaborators and their organization within the system and relating to the whole system.

From the complex thinking perspective, it is possible to understand collaboration in terms of interactions and exchanging information. The organization can provide new features for the system and these new features could emerge as new arrangements and collaboration. Local contexts can be considered to provide inputs to the system. It is important to list some desirable

aspects to deal with, mainly to promote people's engagement. It is also important to list what aspects of the local context should be considered, given that external inputs exchange information with elements within the system and changes can occur as an outcome of the system.

#### 4. Final considerations

Using the complexity perspective to understand and analyze the relationships among all elements in design process open to a world of possibilities in which each element, e.g., individuals, environmental inputs, and even individual actions during the design process, can define the outcomes. Collaboration is not a matter of co-creation or co-authoring, but how every individual or element can contribute to the process and change it according to its own properties, knowledge, and abilities. However, it is also important to recognize and aggregate properties, knowledge, and abilities from other sources in order to establish interrelations, on which a complex system is based, according to Morin's thinking.

Interrelations also intensify the idea of a networked world. By producing and exchanging information through digital media, interrelations among all participants in the design process can become stronger and this new organization of the system can reflect in further collaborative actions. For example, other cultural actions could emerge from interrelations among communities and cultural agents. Or else, urban furniture could be developed from interrelations among communities, local industry, and architecture students. The possibilities are manifold and the complexity approach can embrace all of them.

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