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Research Article

On-Site Participation for Proto-Architectural Assemblies Encompassing Technology and Human Improvisation: "Fish Trap" and "Orchid" Architectural Interventions

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This research investigates the notion of builders' on-site engagement to physically build architectural interventions based on their demands, spatial requirements, and collaborative improvisation enhanced with the principles of uniqueness and bespoke solutions which are previously explored in computational models. The paper compares and discusses two physical installations as proto-architectural assemblies testing two different designs and building approaches: the top-down predefined designers' scenario contrary to bottom-up unpredictable improvisation. It encompasses a building strategy based on the discrete precut components assembled by builders themselves in situ. The paper evaluates both strategies in a qualitative observation and comparison defining advantages and limitations of the top-down design strategy in comparison with the decentralised bottom-up building system built by the builders themselves. As such, it outlines the position of a designer within the bottom-up building processes on-site. The paper argues that improvisation and builders' direct engagement on-site lead to solutions that better reflect human needs and low-tech building principles incorporated can deliver unpredictable but convenient spatial scenarios.

1. Introduction

The team of 16 self-builders, students of architecture from the Department of Architecture at the National United University in Taiwan, built two small-scale pavilions following the principles of decentralised discrete assemblies[1] to test the aspects of improvisation and collaborative negotiations in a crowd-driven assembly [2]. This activity was conducted at the Fabrication Festival, 2018, in London, established by the University of Westminster.

This research study aims to reveal limitations and to outline a position of a designer in collaborative building processes as well as a position of self-builders to investigate potentials to support productivity and efficiency in building and construction sectors. The built installations serve as a testbed for top-down design and building process in comparison with the improvisation and collaborative design strategies leading to two proto-architectural objects, possibly applicable as embedded urban interventions as artistic installations in a public space. The working hypothesis was outlined as follows: the building process based on bottom-up negotiations and improvisation of builders will lead to more flexible and open-ended design solutions adaptable to various conditions and with unique visual qualities and unpredictable design outcomes.

1.1. Rationale of On-Site Building Strategies by End-Users.

There is an increasing trend in the construction strategies and building methods in which end-users build their built scenarios by themselves. This applies especially in the cities with informal settlements, such as Rio de Janeiro, Medellín, or many other cities across the continents. The presence of informal settlements in cities is prevalent in many countries, especially those coping with increased population and urban growth, migration, and poverty where end-users, citizens, and urban communities have an urgent need to build a home or a shelter in a short period of time [3]. Architects, urban planners, stakeholders, and other parties involved in the design and planning processes within cities need to be able to react on such situations appropriately, providing guidelines, principles, and methods how to improve urban and spatial conditions for citizens—however, this is a complex task, not addressed in this article from all perspectives. One of the building methods where citizens and self-builders are involved within the building processes is application of kit-of-parts systems as discrete components, which are precut or prefabricated in the factory, delivered on-site, and assembled by self-builders themselves [4].

1.2. Expected Relation to the Real-World Practice. Participatory construction and building methods from predefined elements and built by self-builders address urban environment-related issues mentioned above in a more efficient and consistent manner and generally facilitate decision-making processes in building activities. Further, these methods tend to increase production efficiency in the construction sector and beyond. Urban communities' values, knowledge of local conditions and current urgent demands and spatial needs embed additional characteristics into the environment, preserving a unique local urban identity and memory-related characteristics in urbanised areas. As such, the strategy of kit-of-parts architecture build by self-builders can bring a new model of circular economy and business strategies to facilitate urban and economic growth within the specific local urban conditions, especially in high-densely populated areas [5]. Therefore, a need to investigate such models is necessary also in the context of contemporary architectural and urban design educational processes to prepare future experts for such challenges.

2. Methodological Approaches of the Conducted Study

This research study aims to explore and investigate the notion of building strategies based on contribution of self-builders, testing two methodological approaches—the predefined scenario from precut kit-of-parts system to assemble predesigned pavilion in contrast with more improvised, nonplanned, stochastic, bottom-up, and open-ended approach to assemble a structure from predefined discrete components. The first method applied in the investigation is a standard kit-of-parts assembly where the builders follow predefined manual and building scenario according to architect's instructions and outlined scenario. Usually such a strategy is based on a graphic manual or project drawings, which are predefined and prepared in advance before any building process starts. In contrast to top-down approach, the bottom-up principle lies on an immediate negotiations and collaborative activation of builders, improvising on-site to deliver demanded scenario, following the present and current interactive process. Within this process, the architect or a designer may give general instructions, which builders may follow as well but without any deeper perspective or a final goal to be achieved.

For the educational purposes, the intention is to understand such a process from the perspective of a builder, how such a process can be perceived, and what the builders can learn from it as well as to reveal limitations of such an approach in order to avoid future difficulties during the process of designing the components and manipulating the assemblies.

3. State of the Art

3.1. On-Site Building Bottom-Up Strategies Conducted by Self-Builders. The research is built upon the idea of building strategies based on builders' improvisation. This was previously explored in proposals by Yona Friedman in Seraj et al. [2], incorporating simple manuals with instructions for builders leading to improvised three-dimensional structures. The concept articulated the importance of simplicity, irregularity, low-tech principles in an assembly process, and its participative nature [6]. Similarly, the open-source movement brings new ideas and building opportunities also to discipline of architecture based on open-sourced and shared data and drawings, such as Elemental studio provided drawings for incremental housing publicly [7]. The precut components or construction systems for self-builders, such as the Wikihouse [8] condensed in a hub, a database of open-source project Bricks [9]. As such, the entire neighbourhood or even a district can be built in such a way[2]. Architects Teddy Cruz and Fonna Forman investigate in a long-term manner a potential for precut building components delivered on-site to provide a kit for end-users' assemblies to cope with the social housing crisis, informal settlements, and migration issues related to wider political or environmental conditions around the Mexican border line with the US [4].

3.2. Pedagogical Approach. At present, educational tendencies in the discipline of architecture and urban design operate with the advent of digital technologies and their incorporation in the design processes, which enrich traditional techniques used in design, building, and testing operations for prototypes or assemblies. However, the importance of hands-on work and manual assemblies in connection with digital fabrication and participatory strategies in contemporary architectural higher educational institutions needs to be articulated stronger as most of the schools' educational processes are based on linear process of learning. The educational process is usually based on a proposal of the concept, development of design, model making, and production of drawings, and the process ends here as there is no 1 : 1 prototype being built, from which the students learn, apart from selected high-end institutions, e.g., the Architectural Association or the Bartlett School of

Architecture, both based in London. In particular, this article refers to Erdine and Kallegias' educational concept [10] to address innovative pedagogical tendencies in architectural education mostly relying on practical hands-on working methods, generative design, spontaneity, user feedback, participation, and human interaction "enabling more seamless transition from design to fabrication and from academia to profession" [10]. Collaborative aspects in the design studios have been explored and investigated by Cabrinha [11] as a platform to discover relationships "between representation, simulation, and physical material in a digitally mediated design education," revealing "underlying principle to form relationships of teaching architecture through digital tools, rather than simply teaching the tools themselves." As such, an active engagement of students in a production and representation based on a "discovery" approach through making, building, and processes-oriented model of design was applied in the following case studies as a main pedagogical driver to activate and motivate the students.

4. Case Studies: Component-Based Pavilions

Following the strategy of previously explained architecture from discrete components and assemblies, the two case studies were built based on the logic of additive material assemblies and aggregative components [12]. The idea of installations was based on aspects of participatory design and building strategies to address potentials for customisation of urban spaces by interacting with the components, as previously explored by Bondin and Glynn [13], using a component device as a building block. Two ideas for the pavilion are introduced in this paper, addressing the component-based building strategy and a participatory experiment for an assembly without any predefined scenario to be built, purely relying on self-builders themselves to test two different methods and possibly reflecting real-world conditions, where builders need to solve any occurring problems in situ.

4.1. Fish Trap Pavilion. Our approach in the first example is based on a strategy without any use of manuals or predefined instructions for builders. The first case study, a Fish Trap (Figure 1), focuses on real-time engagement of builders in a building process dealing with predefined building blocks, deployable through the participatory design activity on-site. Our intervention, an abstract representation of a "fish trap" as a decentralised system of modules assembled together in a nonhierarchical manner, enables the possibilities of spatial aggregations into more complex morphologies based on mutual negotiations between the builders. The general idea was based on a predefined object in the form of an irregular polyhedron, a building block, which allows the builder to combine, assemble, and aggregate objects into various spatial variations creating customised architectural and urban space according to spatial necessities and aesthetic preferences.

The components were attached to each other, creating a self-supporting structure, which can grow in time and space, following the logic of diffusing and aggregating components. The polyhedron component has a variety of possibilities of face or edge connections. This brings an endless amount of open-ended spatial and structural solutions, which can be speculatively considered as either artistic installations, interior design elements, or urban interventions in a given public space. The possibilities for occupancy will depend on the scale and the context.

The components were precut from two-sided cardboard material utilising a laser cutter. The cut and unfolded sheets with the components were delivered on-site and handed over to self-builders. There were three leading designers present on-site, and they moderated the builders to creatively react on given conditions, considering builders' skills and capacities to respond to specific tasks. The building process itself was based on an improvisation reflecting direct participants' design intentions, negotiated and interactively applied during the building process.

4.2. Orchid Pavilion. In the second intervention (Figure 2.), the overall space is displayed with constructions based on three-legged units, inspired by "Ding," a traditional ancient Chinese cooking utensil. Its purpose has evolved into a ceremonial device which symbolises the domination of the kingship and the endlessly offspring. Its form and image represent the permanence and inheritance of the Chinese culture. The rules of assembly in this case study were strictly predefined by the designer, leading to one possible and unique spatial solution. However, as the mode of an assembly is based on slotting and mounting techniques, and the material chosen allows customisation of the components, it was assumed that such assembling strategy could yield a variety of design solutions as well. As such, the strict top-down approach can be easily redefined and customised according to the spatial demands later on. The units are combined together, forming into pillars, and eventually, the pillars merged and formed a dome. The pavilion is intended to display a variety of heights, mesmerising visitors with a sense of traveling into an ancient street.

The form of the architecture was inspired by the three legs, which a ding stands on, and the final achievement was also complied with the rule of a triangle. The body parts of the pillars are resemblance of the supportive walls of a ding. Assembling in a trigonometric matter, the top of the pillars was extended to form a classic triangular dome, and the rest of the pillars extended in all directions was demonstrated intentionally as unfinished domes to echo the promising possibility of Chinese traditional architecture.

The design process led the builders to start from the bottom to the top through the 3D model, which served as an initial exploration in the computer. The model was simultaneously translated and explored through a variety of different design ideas with aspects of user-oriented scenarios. The ultimate goal was to create new construction forms and innovative solutions to replace existing architectural forms with simple thinking.

Figure 1: The Fish Trap installation consisting of predefined precut components. The intervention was built on-site based on improvisation and collaborative design strategies. The possible spatial scenarios had been simulated computationally using stochastic aggregation strategies. The designer designed the building block only, which allows builders to build an endless variety of outcomes.

In the current common form of construction, the general construction module usually uses the "Fragment Geometry" to construct the fragmented unit to a huge entirety, and finally groups the main type together to challenge a structural form [14], but a bolder approach in the thinking of The Orchid Pavilion design was taken. A large area and efficient structural unit modulus were expected to be completed. At the same time, a different functional form through cutting and fine-tuning was made in order to achieve an efficient structure. Considering the construction method, this approach still maintains the logical thinking of building of basic units of the column, bridge, and board as a structure to provide continuous expansion into real building forms in the future.

5. Evaluation and Observation

The following comparative criteria have been applied to evaluate the results: material efficiency conveyed on-site, aesthetic and spatial qualities, flexibility and adaptability of the assembly for different spatial scenarios, ability of the assembly to be scaled up or to grow, and immediate reaction of the builders on-site.

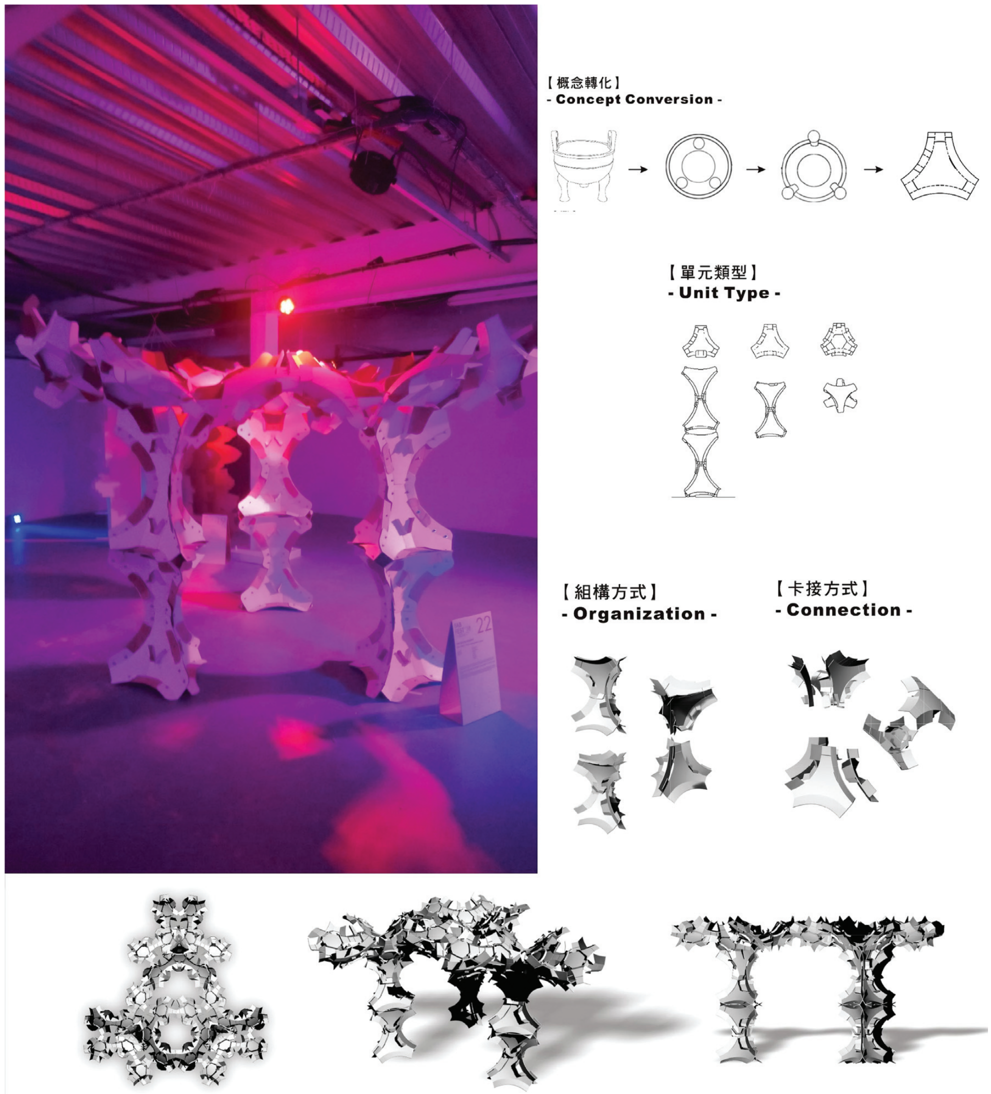

FIGURE 2: The orchid pavilion, a proto-architectural object assembled of discrete components and following more traditional form of Chinese architecture. The concept had been predefined by the designer with precise and specific means, computationally simulated, and visually analysed before the production and installation was made.

The results were evaluated by visual qualitative observations, following the above-mentioned criteria. The qualitative feedback from builders pointed how they were activated and collaboratively engaged in the process of an assembly. From the qualitative observations, the issues and limitations of the method and advantages or disadvantages during the building process were discovered and understood. It has been observed that the bottom-up assembly strategy was more difficult to conduct as there were no predefined rules, and the builders were improvising. The presence of the leading designer on-site was necessary in both cases.

A variety of spatial scenarios had been computationally simulated first, before the fabrication and assembly were made. As the Orchid pavilion has strict predefined rules of an assembly consisting of several types of components, this solution is more rigorous but not necessarily allowing more flexible spatial scenarios. On the contrary, the discrete component-based Fish Trap pavilion allows better flexibility in terms of different spatial solutions for an assembly. The stochastic computational model for an aggregation of components was tested in order to outline a variety of possible solutions for the assembly, although the final scenario did not follow any of those scenarios. This proves that using the decentralised approach of design and building strategy leads to unpredictable and endless variations of spatial solutions.

Aesthetic and spatial qualities are observable in both case scenarios, and more convincing and attractive pavilion was found which is the Orchid. However, the ability of the system to grow or be scaled up is present better in the Fish Trap pavilion as it encompasses open-ended solution for the assembly by means of discrete building blocks, only depending on the amount of the components. For the assembly, there were used 180 individually laser precut components.

5.1. General Observations. Based on a qualitative comparison, it was observed that the flexible and adaptive scenario based on the same discrete precut components is more convenient for improvisation and bottom-up assembly, but it brings another level of complexity into the building process which needs to be moderated by the designer. As such, although the improvisation on-site yields unexpected and unplanned results in unpredictable spatial scenarios, the presence of the designer on-site is still needed as he mentors and navigates the builders to deliver spatially convincing, meaningful, and architecturally and artistically appealing result. As such, the working hypothesis has been confirmed. However, this research did not reveal the potential and abilities of nonexperts possibly involved in the design and building process as the builders in this study were students of architecture. For that reason, the future research will test the engagement of nonexperts as builders in a real-world case scenario to outline the specific local demands for customisation and adaptation based on unique local requirements.

The installation of both pavilions was a test of the concept of on-site design participation, where the assemblies were delivered based on either top-down or bottom-up building strategies. Bottom-up negotiations of builders brought unpredictable form of a design solution. Predefined objects allowing open-ended configurations based on a simple rule-set proposed by the designer yield a variety of more complex aggregations with certain uniqueness in visual expression. Further, the results indicate that such a concept can grow and possibly be scaled up to wider spatial scenarios based on the uncontrolled decentralised approach by adding more components to the core agglomeration.

As it was expected in the assemblies' initial objectives and confirmed in the final forms of assemblies (especially in the case study of the Fish Trap), the outcomes seem more sculptural than architectural. However, there is a space for further speculation of possibilities of occupancy of such an intervention. As discussed above, such an assembly can be embedded within the urban context to activate and facilitate people's engagement to interact and physically manipulate with the objects.

5.2. Personal Conversations and Feedback

5.2.1. Feedback during Learning Process. Personal conversations with the builders were conducted during (i.e., July 2–6, 2018) and after the building processes (August 2018) between authors and student participants. The outcomes from these conversations which have been statistically involved in the production mainly aim to explore and discover potentials for the effective learning process. "The Orchid Pavilion 3.0" made the builders feel the stability, certainty of the design, and organization process during the learning activity. Especially, the time control and the level of completion led to decisions that are more confident during the building process in this case. This is also more evident in previous learning projects and study lists. Because of the features with timely adjustments and corrections, this is apparent that the learning projects fully demonstrate and reflect the practice, traditional learning, and consequently overall efficiency of the design studio learning activity.

The initial learning process of "The Fish Trap" made the builders feel at a loss because they could only confirm the shape of the unit and had no idea how the final group composition and type will be. This will lead to a conclusive statement that certain envision of the potential outcome which is going to be built is necessary to provide to builders at the beginning of the assembly process. Although the process was based on a random improvisation, however, the situation led the builders to the point when there was no choice for additional variations of an assembly, and they spent a lot of time digging the construction of the units and created some random type of an assembly, with no deeper consideration or an aim they should achieve.

5.2.2. Feedback Related to the Results. It was generally considered that "The Fish Trap" concept must spend more time on discussion and communication while following the notion of prosperity, meeting the common goal, and overall openness to further changes. The efficiency and the results are filled with uncertainty and unpredictability. People think this kind of operational mode seems to be more as an artistic creation rather than a design work following specific goals. However, the strategy was spontaneous, creative, and opens new possibilities to think about architecture from different perspectives, mostly relying on volumetric qualities and unique formal expression. This may serve as a public attractor in a given urban scenario. Contrary to the previous solution, "The Orchid Pavilion 3.0" obviously has quite significant design features, and the result is easy to be predicted because of its integrity and regularity. Although it maintains a stability and effective result above the standard, the operating process is not as easy as people think so. The whole process depends on the ability of design decision makers or the amount of builders. However, there is no doubt that the process is completely under control, and the results are significantly controllable.

5.3. Outcomes. As a result, two proto-architectural systems have been erected as installations, consisting of a set of simple predefined modules which can be assembled, reassembled, and assembled again in different configurations by the end-users on-site, leading to a diverse number of more complex spatial variants (Figure 3). These can be embedded within a public space as a demonstration of approaches taken during the process.

6. Overall Benefit and Contribution

There are two main contributing and beneficial aspects, discussed as follows.

6.1. Contribution to Pedagogy. The main benefit, which students can take from the study, is the experience-oriented learning through making. The students learnt how important is the negotiation, communication, interaction, team

Figure 3: Two proto-architectural interventions built on-site based on collaborative design strategies: top-down design process and bottom-up on-site interventions.

work and sharing the ideas, and knowledge acquired during and after the process. This may inform their further personal training in the discipline of architecture. Moreover, such a pedagogical strategy could be applied in educational processes more frequently in order to articulate hands-on working within the context of digital technologies, following the idea of spontaneity, participation, and predefined kits-of-parts component design and preparation. This strategy can be applied in all levels of learning in a vertical manner (lower level students can work with more experienced students and learn from them). The students participating in these two studies were undergraduate students. A model of learning through making will yield better-oriented experts in the discipline, capable to solve any particular problems more efficiently.

6.2. Potential Strategies for Real-World Participatory Construction Methods in the Future. This experiment confirmed that, for future participatory construction and building strategies, the self-builders need to be moderated by the designer or need to follow a predefined manual for an assembly unless there is no specific goal that needs to be achieved. The approach introduced in this paper, investigating a direct involvement and participation of users and utilising participatory kit-of-parts systems and components, will bring transparency and productivity-efficient building processes if applied in real-case scenarios. In addition, the participatory building method allows further postassembly and postactuation building processes to reconfigure and modify the given built solution. This approach is out of traditional scheme of client-contractor-supplier chains. Rather, it articulates values and knowledge of local urban communities, their skills, and with a prospective consideration of local resources and particular conditions only known to interacting participating parties. In that sense, the citizens themselves can improve the environmental conditions, liveability, production, and can contribute to the overall common improvement and efficiency of built environments.

Data Availability

The visual data used to support the findings of this study are included within the supplementary information files. The data used in this manuscript are based on qualitative observations, documented in photographs. The documentation is available in [15]. In addition, a supplementary video material is available in [16].

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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