THE ARCHITECT AS TOOLBREAKER?

Probing Tool Use in Applied Generative Design

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Abstract. This paper investigates whether generative design tools can perform their intended functions after being passed on from the contexts of their production to different application contexts similar to the way that other tools such as hammers or bicycles are. We report on a design studio application of two generative design tools and relate observed design processes and outcomes to our toolmaking intentions. Our findings suggest that, at least in the case of the examined tools and workshop, tool use in generative design tends to defy toolmaking intentions. We discuss the consequences for generative design toolmakers and conclude with some speculations on possible solutions.

1. Introduction

The development of tools and methods, similar to the development of theories or products\(^1\), is widely understood as contributing to communities or groups of users. Tools are thought of as being designed and implemented by someone for someone, oftentimes someone else, whereas for a given tool, the group of users is usually considered to be larger than the group of developers (the same goes usually for products, methods and theories). In this sense, it is assumed that the user of a tool has likely not been involved in its ideation and development. This is true in cases as diverse as the hammer, the Chinese abacus, the bicycle and Adobe Photoshop (tools) as well as the Rule of Proportion (method), the Volkswagen Beetle (product) and the General Theory of Relativity (theory)\(^2\). The understanding of design tools and methods described above can be explained in the context of

\(^1\) We regard products as results of the application of tools or methods, tools as manifestations of methods and methods as applications of theory.

\(^2\) The understanding of how each of these items should be classified in a given situation is in the eye of the beholder. We hope the classification shown here is agreeable enough to support our argument.
specialization and modern division of labor. Not everyone has the resources necessary to make a software package or an automobile but many people feel the need to use them. The field of computer-aided design has apparently adopted this model. Ayrle (1991), p. 94 suggests a distinction between the levels of users and developers of computer tools for architects. Analogously, the success of commercial three-dimensional modeling packages and their wide-spread use in educational and commercial design studios may be seen as a confirmation that the described role allocation is effective in toolmaking for design. Research publications within the more narrow area of computer-aided generative design suggest similar scenarios. By computer-aided generative design we mean approaches to design process support that utilize computational power to create or reduce form variation in either partially or entirely automated fashions, whereas the key software tools usually run within or in conjunction with standard CAD packages or graphics libraries. Previous reports on generative design software development initiatives implicitly or explicitly refer to the support systems they produce as “tools” and their general applicability is suggested by references to the tools’ anonymous “users” or “designers” in the third person. Examples include Frazer et al. (1999), Achten et al. (2000), Fischer and Fischer (2003) and Chase (2005). Intentionally or not, these accounts present generative software tools in analogy to tools like hammers, can-openers and bicycles in the sense that these tools are made by few in order to be applied by many, as well as in the sense that the toolmakers’ understanding of how a task should be performed matches that of the tools’ future users. This assumption of generalizability usually remains implicit as typically no deviation from the one-for-many tool making approach is discussed in these reports. During our own practice of making and applying digital tools for generative design we have grown somewhat doubtful of the idea that generative design software is as generalizable and transferable from one designer to others, and from the context of production to other design contexts, as has been previously implied. To examine this issue in order to inform future toolmaking initiatives in the generative design field, we conducted and monitored a design workshop, in which two of our generative design tools were applied. We examined the relationship between our intentions for the tools’ application and the observed modes of application and resulting outcomes with respect to purpose and abuse, design approach and user role allocation.

2. Method

To explore whether if tools for generative design can be purposefully passed from the context of their production to other contexts, we identified three aspects in terms of which tool applications could diverge from toolmaking intentions. These three aspects, briefly outlined in this section, were used as primary measuring devices to investigate the research question.

Based on their theoretical and methodological underpinnings, generative design approaches and related tools have been described and classified as either “top-down” or “bottom-up” oriented. Schmitt (1993), pp. 42-45 gives a basic discussion of both approaches. More recent examples include Chase (2005) and Scheurer (2005). In the case of top-down orientation, initially defined expressive gestures are iteratively differentiated to fulfill some
additional design criteria. Parametric geometry variation is an example. In the case of bottom-up design, configurational rules are iteratively applied to generate forms that are initially hard to predict. Cellular automata-based composition of form is an example. We regard one of our tools as bottom-up oriented and the other one as top-down oriented. To assess whether this distinction has an effect on the use of the tools, we asked the workshop participants to rate (on a scale of 1 to 7) whether they used the tools primarily to realize ideas they had before they started using the tool (1) or to generate ideas through exploration and experimentation (7).

Another aspect relevant for tool use in design is that of how a joint creative effort is orchestrated within a group of designers. Kvan (2000) draws a distinction between close-coupled collaboration and loose-coupled cooperation of designers. He argues: “A loose-coupled design process requires a very much different set of tools and conditions to be successful than a close-coupled one” (p. 415). Inverting this argument, it could be expected that there would be a distinct type of tool appropriate for each kind of collaboration. The GUI interfaces of both of our generative design tools occupy less than 1/8 of the screen surface and are operated sequentially via keyboard and mouse. Largely determined by our intentions at earlier stages of the tools’ development histories, their interfaces favor individual use and hence processes of loosely-coupled design co-operation. By observing to which degree the tools are used in loose or close coupling, we aimed to obtain indications regarding the degree to which toolmaking intentions shape tool use. For this purpose we asked workshop participants if they used the tools (A) always individually, (B) always working closely with group members or (C) both.

Glanville (1992, 1994) distinguishes tools from media. As a tool, the computer can responsively follow user instructions and intentions preconceived by the toolmaker. As a medium, however, the computer can lead the user to results that were neither intended nor expected by the toolmaker or the designer, and thus plays an interactive role in the design process. To examine if and in what ways both tools might have acted as media during the workshop, we observed the design processes and examined the digital material generated during the workshop, seeking types of results that were different from the conceptions we had when making the tools.

3. Workshop setup

The design studio workshop titled Tofu Cubes and Soap Bubbles was conducted during a five-day period in April 2006 at the Department of Architecture of the National Cheng Kung University (NCKU) in Tainan, Taiwan. Seventeen Masters and PhD level postgraduate students took part as members of five design groups. Six weeks before the workshop, all students were given a list of ten introductory readings in the area of non-standard architecture and generative design. Both tools as well as the software environments in which they are embedded (MS Excel, 3D StudioMax and Rhino3D) were installed on all desktop computers in the workshop space and also made available to students for installation on personal desktop and laptop computers. Students were given an overview of generative design approaches in a lecture on the evening of the first workshop day, followed
by a question and answer session and an introduction to the tools in a seminar-style setting. All groups were given the same, relatively open design brief, which asked for an extension to the NCKU campus to host additional space for the architecture department. A list of functions and specifications was given to the students to provide a framework for those who might find a vague design brief too challenging. We nevertheless encouraged deviations from and re-interpretations of the brief according to the students’ interests and no more than preliminary, conceptual results were expected within the short time frame of the workshop. Corresponding to the two different purposes for which our generative design tools were developed, the new building should consist of concrete building mass and glazed space frame structures. Students were free to utilize any resources and tools they wished to use in addition to our two tools, in their design processes.

The Tofu Automata Generator (TAG) is a 3DStudio MAX script, accessible through the graphical user interface of a 3DStudio MAX utility. The script enables users to generate complex assemblies of white box shapes, hence the name of the software. Four basic materials are available to assign to box shapes in a 3DStudio MAX scene: “matter”, “void”, “context” and “neutral”. Objects with one of these materials may then be repeatedly transformed geometrically either manually or through a number of predefined functions (see figure 1). Intended for bottom-up form generation, this tool supports processes that oftentimes lead to unexpected results. The TAG is one of a series of test implementations exploring the potential of cellular automata as architectural design support tools (see Herr and Kvan 2007). After previous implementations focused on allowing users to configure rules and relationships between volumetric elements, user tests have indicated a high demand for more automated functionality with potentially surprising results and less time spent in rule configuration. The TAG was thus developed to offer a range of easily accessible predefined functions to generate complex forms based on given box shapes.

Figures 1 and 2. TAG and SBTCR quick-start cards handed out in the design workshop.
The Soap-Bubble Truss Co-Rationaliser (SBTCR) is a VBA macro script implemented in MS EXCEL and Rhino3D with a graphical user interface (see figure 2). It allows the editing of close-packed sphere structures or “bubbles” and their translation into corresponding space frame structures, hence the name of the software. Individual bubbles can be assigned virtual “pressure” parameters to obtain bubbles of different sizes within the same cluster. Different sphere packing structures and their corresponding space-filling polyhedra are supported as three basic working modes: rhombic dodecahedra as described by Fischer and Fischer (2003), Kelvin cells and Weaire-Phelan foam, both as described by Weaire (1997) and Bosse (2004). The toolmaking intention behind this software was to allow the top-down differentiation of user-defined spatial volumes into space frames of irregular appearance with minimal numbers of necessary building elements. Supporting extensive flexibility in its open-ended use, the tool deviates from what have been described as pre-rationalisation and post-rationalisation approaches to complex geometry rationalisation. We see it as supporting “co-rationalisation” as described in Fischer (2007). The development of this tool has been inspired by challenges arising from the design of the Beijing National Swimming Centre by PTW (Sydney), ARUP (Sydney) and the China State Construction and Engineering Corporation. It was later applied by T. Fischer in collaboration with PTW and ARUP in a project submitted to the Tsunami Memorial Design Competition in Thailand in late 2005.

4. Process observation and design outcomes

During the workshop we provided tutorial support and commented on the resulting design work in the context of a final critique. Apart from that, we observed the five groups’ design processes at four different levels: We took field notes during the tutorial interaction, focusing on events and observations that seemed interesting, unexpected or otherwise relevant with respect to differences in our and the students’ way of using the digital tools. Students maintained self-observation notes, recording times and types of activities involved, respective environments, resources used and related remarks. Before the final critique, we conducted a questionnaire with individual students and after the final critique we collected all digital material produced by all groups during the workshop. All groups designed, presented and discussed interesting and original designs on the 5th and final day of the workshop (see figure 3).

Figure 3. Samples of workshop results: 1) Exhibition system in staircase 2) Canopy structure in vernacular city context 3) Campus extension with canopy 4) Tree house 5) Kinetic library.
5. Findings

Thirteen participants used the TAG and 15 used the SBTCR. While we regard the TAG as a bottom-up design tool and the SBTCR as a top-down design tool, the participants rated their uses on average 5.1 in the case of the TAG and 5.5 in the case of the SBTCR (1=I used the tool to realize ideas I had from the beginning of the workshop, 7=I used it to explore and experiment). It seems that both tools were applied in predominantly bottom-up ways, the one we thought of as top-down even more so than the one we regarded as bottom-up. While we regard both tools as supporting single-user dialogues best and favoring loosely-coupled design processes, only one user of the TAG always used it by herself, four always used it working closely with group members and eight went back and forth between both modes. None of the users of the SBTCR used it entirely by themselves, seven used it working closely with group members and eight worked in both modes. There were at least four cases in which our tools were used in ways we did not anticipate (see figure 4 for examples). Group 1 was inspired by forms generated with the TAG, but then modeled a related form by other means. Group 5 was conceptually inspired by geometrical translations observed in the same tool, then proceeded to design an adaptive kinetic library system without applying either tool. Group 2 used the SBTCR to generate an irregular canopy structure in conjunction with other tools and used the TAG, which is intended for non-deterministic form generation, to generate a model of the project’s site context. Group 4 found previously ignored ways to obtain “inverted” shapes by exploiting extreme parametric relationships and interpreted the results as furniture and similar interior design elements. Users also requested additional software features such as a form·Z export filter for the SBTCR, which we were able to provide during the workshop, as well as ways to multiply soap bubble clusters generated with SBTCR in the TAG, which was impossible to achieve before the end of the workshop.

![Figure 4. Examples of tool re-appropriation.](image)
6. Discussion

Our observations can only be limited as we have tested only two generative design tools in only one workshop. From our own experience we know that with increasing mastery of a tool, the modes of its use change and adapt over time and it might very well be that the five-day period of the workshop was not long enough for this adaptation to become effective. Nevertheless, our findings in all three examined aspects are counter-intuitive to the idea of passing generative design tools purposefully from the context of their production to other contexts. Tools for designing seem to differ significantly from other tools such as hammers and bicycles in this respect.

In our view, the purposeful generalization of a design tool requires some coincidence between the user’s design intentions and the toolmaker’s understanding of the user’s intentions. In generative design, however, as shown in the study presented here, this seems to not always be the case. If a tool proves useful to a user for a purpose that was not considered by its toolmaker, then this usefulness must be described as either accidental or as a result of abuse. From the perspective of an outside observer, then, any other resource, being most likely equally unintended for the given design intention, could have proven just as useful to the user as these tools that became useful through accident or abuse. From the perspective of the tool user, as shown in our study, the act of choosing a tool as well as new concepts that emerge through its use, have an actively shaping influence on the design process. The task of the digital design toolmaker becomes complicated and compromised. If some aspects of the usefulness of one’s products depends on accident or abuse, then there is little to be learned from user observation in the way designers learn from observing the use of hammers or bicycles (whose makers and users we believe have some coinciding understanding of their use). Seeking a possible way out, toolmakers might look towards the support of tasks that are sufficiently “pure”, closed-ended and tamed (Rittel and Webber 1984), in the way in which CAD packages support tasks of pure geometry. In this case, however, it could be argued that software acts as a tool and not as a medium in Glanville’s (1992 and 1994) sense and hence does not support the design process itself. Moreover, generative design tools usually appear too “biased”
towards specific types of forms and processes to qualify for this approach. The chances for providing generative design support in a directed manner by means of toolmaking appear slim – unless, possibly, at least one of the following two conditions is fulfilled, which have not been examined here and which we are planning to investigate in future research:

- Makers and users of design tools “conspire” i.e. operate within the same design context (project) and share a similar view of the tasks at hand. In the extreme case, the sufficiently skilled designer would make her or his own tools as we do and as described by Ceccato (1999).
- Toolmakers find modes of generative design support in which tools are used as intended by their developers, yet support the systematic generation of new thoughts, ideas and understandings in the process of their use, possibly by exploiting ambiguity in conceptual representations in a way sketches have been described to do (see Gross and Do 1996).

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