AN ETHNOGRAPHIC ENQUIRY INTO DIGITAL DESIGN TOOL MAKING

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Abstract. This paper presents an ethnographic pilot study into the design and application of digital design tools in a leading Shanghai-based architecture and engineering firm. From a participant observer's point of view, we employ qualitative research methods to enquire the conditions and experiences entailed in day-to-day collaborative activities in conjunction with the custom-development of digital design tools in advanced practice. The described initial ethnographic enquiry lasted for six weeks. While previous studies tended to favour post-rationalised and outcome-focused reports into toolmaking for design, we observe through participant observation that daily collaboration in practice is multi-faceted and overwhelmingly more complex. This paper further portrays and reflects on the concomitant opportunities and challenges of participant observation as a research method that can bridge academia and practice. We argue that, in order to appreciate and to inform digital design toolmaking practices, it is essential to recognise the richness of practice, in and of itself.

Keywords. Digital design toolmaking; custom-developed tools; collaborative processes; ethnography; participant observation.

1. Introduction

With the growing importance of landmark architecture and the digitalisation of advanced design practice, parametric façade design requires project-specific design workflows as well as custom-developed digital tools (Santos et al., 2012, pp. 87–88). In many advanced architectural and engineering practices, digital design toolmaking has prompted the rise of multidisciplinary teams consisting of architects, engineers, consultants, and other experts – who collaborate closely with one another on a day-to-day basis (Altintas et al., 2019, pp. 333–334). Despite having gained considerable importance in practice, however, design toolmaking processes remain largely unexplored as a subject of academic research.

Previous research tended to focus on features, capabilities, applications and outputs of digital (design) tools, often neglecting the conditions and the "design experiences" (Yaneva, 2009, p. 104) entailed in daily collaboration between tool users and toolmakers. This study investigates how custom-developed digital

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design tools take shape within applied façade design and fabrication practice, specifically at Rice Francis Ritchie (RFR) Shanghai – a firm that is known to create and apply custom tools on a per-project basis. We employed participant observation and the analysis of field notes – an ethnographic qualitative research approach that is gaining popularity across the architectural landscape. The purpose of our investigation is to shed light on a unique culture of practice-based collaboration, its design decision-making, its division of labour as well as other types of negotiation that underpin the day-to-day creation of digital tools in advanced practice. The data and insights presented in this study are expected to provide a foundation for further research in this area.

2. Digital design tools

"Tools mediate our engagement with the world." (Baber, 2003, p. 3) They are integral to our self-image as humans. Tools are artefacts or systems by which we affect change. They are particularly relevant to us where our agency relies on technology, which is the case, in particular, in the design context (Fischer, 2008, p. 12). In industrialised contexts, tools are typically created by someone for someone else, and, usually, the toolmaker (who can also be the tool user) knows and understands the future application of the tools (Fisher and Herr, 2007, p. 381). "It is assumed that the user of a tool has likely not been involved in its ideation and development" (ibid.). This is certainly the case in the development and application of Computer-Aided Design (CAD) software packages, as designers do not necessarily have software development skills (ibid., p. 382). Furthermore, tools are commonly made by few, to be used by many. The generalisation at play here may not be applicable in digital toolmaking, as the custom design tools tend to addresses highly particular design challenges.

2.1. COMPUTER-AIDED DESIGN (CAD) TOOLS

Following the Second World War, the initial development of CAD systems was a part of a broader effort to convert wartime technological advances for commercial use. Bottazzi (2018, pp. 9–11) explains that military technologies were stripped down to "their more general features in order to make them applicable to as many problems as possible, including unforeseen ones". Through recurring feedback and iterative evaluation from users, software engineers could generalise patterns of paper-based design practice to digital techniques. On the following years, this propelled the development of early CAD tools (ibid.). Collaboration between users (including designers) and software engineers prompted the development of more robust CAD packages which, as digital technology became more accessible to designers, infiltrated design offices and education (ibid.). CAD tools increased productivity, particularly in the transition of conceptual design from offices to construction sites. Architectural firms such as Gehry Partners, Eisenman Architects, and Objectile are known to collaborate with software developers from the ideation to the realisation of specific CAD tools (ibid.).

2.2. PARAMETRIC MODELLING

The increasing pervasiveness of parametric thinking and modelling in present-day architectural arenas can be seen as a response to the limitations of conventional CAD packages, which operate in chronological and linear ways – often defining geometric entities independently without any associativity with other entities present in the interface (Goldberg, 2006, pp. 102–103). Parametric systems introduce a shift from conventional drawing methods (as in the case of 2D and 3D drafting) that nurture "the propagation of the difference" and "repetition of the variation" – the *sine qua non* for "non standard", yet precise design proposals (ibid.).

In his dissertation, Davis (2013, pp. 14–15, 30–32) observes that numerous definitions of *parametric modelling* tend to focus on its propensity to generate output rather than on its functional mechanisms. In an attempt to link parametric modelling back to its original meaning devised through the collaboration of pioneer scientists and mathematicians in the nineteenth-century (ibid., p. 31), Davis suggests that a parametric model should be seen as "a set of equations that express a geometric model as explicit functions of a number of parameters". While it is understood that parametric modelling augments designers' agency through the variability of outcomes and potentially assists design processes, it has often been criticised for its reusing and sharing inadequacies (see section 6) (ibid., pp. 40–41, 45).

2.3. CUSTOM-DEVELOPED DIGITAL DESIGN TOOLS

"Digital design is now fully assimilated into design practice, and we are moving rapidly from an era of being aspiring expert users to one of being adept digital toolmakers" (Burry, 2011, p. 8). Designers are shifting from 'mere' parametric modelling to adopting scripting cultures – ongoing practices that are encouraged in both education and professional environments. They account not only for the extensive body of work in that area but *de facto* also for the rise of interdisciplinary collaboration between tool users and toolmakers to provide a more communicative and supportive interface for architects, engineers as well as other allies within and across AEC teams (Qian et al., 2010, p. 58).

The development of in-house project-specific digital design tools is now commonplace in advanced architectural and engineering firms such as Gehry Partners, Foster Partners, ARUP, and RFR, amongst others. These custom-developed tools are relevant where particular design challenges are addressed that include, but are not limited to: "(1) design task automation, (2) extension of CAD application features, (3) customisation and procedural generation of parametric models, (4) algorithmic exploration of different design options, (5) 3D printing optimisation, (6) implementation of digital fabrication protocols, (7) deal with complex models, and (8) pursue exhaustive design exploration through the manipulation of scripted parametric models" (Santo et al., 2013, p. 87). The current practice has generated a new group of specialised digital toolmakers who support "design projects with specific tools as needs develop in the context of applied design projects" (Fischer, 2008, p. 4). However, research on

how digital design tools take shape and on the nature of collaboration among tool users and digital design toolmakers remains scarce as "failures and dead-ends" are often masked in reports (ibid., p. 245).

2.4. COLLABORATION AND CO-OPERATION

Digital (design) tools have changed collaborative activities among designers both across professional and educational platforms (Kvan, 2000, p. 409; Santos et al., 2012, p. 90). In his research on the nature of collaborative work in design practices, Kvan distinguishes two modes of joint creative effort among design team members – *close-coupled collaboration* and *loose-coupled co-operation* (see Figure 2) (Kvan, 2000, pp. 410–412). He postulates that many design activities constitute loose-coupled co-operation – with each actor within a particular design community contributing to different aspects depending on their expertise and "knowledge appropriate to the situation" (ibid.). However, based on the qualities of close-coupled collaboration, Kvan argues that "A loose-coupled design process requires a very much different set of tools and conditions to be successful than a close-coupled one" (ibid., p. 415). Fischer and Herr (2007, p. 383) echo Kvan's position and suggest the possibility of having a "distinct type of tool appropriate for each kind of collaboration".

2.5. RESEARCH GAPS AND MOTIVATIONS

There has been a large number of reports on the production and use of digital design tools in the CA(A)D field. Many of these reports are post-rationalised and outcome-focused, with a tendency towards describing features, applications and outputs of tools (Fischer, 2008, p. 245). The conditions and experiences entailed in their design and development, by contrast, remain unexplored. Furthermore, Yaneva (2017, p. 160) argues that theory-building has a propensity to simplify and purify the practice of architecture. In her ethnographic enquiries on diurnal collaboration in applied practice, she posits that other actors, such as clients, contractors, governmental bodies, and many others, possess the ability to influence design decisions, processes and making. Accordingly, in order to inform design practices, it is essential to do justice to the richness of day-to-day collaboration in practice. This paper investigates and highlights how custom-developed digital design tools take shape within applied parametric façade design and fabrication practice at RFR Shanghai. Through participant observation and the analysis of field notes, we record and examine the "performative and fluid" (ibid.) dances of agency embedded in daily collaboration between architects, engineers and other allies of the profession in support of digital design toolmaking.

3. Study framework

The scope of this pilot study is limited to the observation of a particular parametric design process for one of RFR's commissioned projects. The participant observation enquiry was carried out by the lead author for six weeks from mid-October until the end of November 2019. Before engaging in fieldwork, we obtained the research ethics approval from our institutional body as well as consent

from our professional collaborators at RFR. The site informants were briefed about this research and the role of the lead author as an *academic researcher* actively contributing to toolmaking initiatives for one of their projects while also ethnographically recording related negotiations, design decisions, strategies and considerations. Following consent approval from our industry colleagues, the lead author engaged *in-situ* at several weekly intervals to participate in, and observe, the design practice at RFR. Our initial observations focused on different modes of day-to-day collaborative activities among the architects, engineers and other professionals. The lead author collaborated with two structural engineers (Florian and Wanning) on the development of a tool to realise a particular idea of an irregular geometric assembly while harnessing sameness for cost-effective batch production for *Tai Ping Qiao Roof Gallery*, a project commissioned by Kohn Pedersen Fox (KPF) architects to RFR.

4. Ethnography and participant observation

Developed by cultural anthropologists, ethnographic research involves observing people's engagement and interaction within the contexts of their living or work to uncover "social data that is not theory-driven" (Lloyd and Deasley, 1998, p. 103). Formerly employed in Non-Western societies, ethnography concerns the study of "how culture is brought to life" (Ladner, 2014, p. 15) and shared through recurring activities of individuals or groups of people in a particular social setting. While ethnographic research seems scarce within the architectural landscape, it is growing in popularity in CAAD research – particularly in practice-based research (Bhavnani et al., 1996, pp. 244–245). For instance, Qian et al. (2010) employed participant observation at *Bentley's GenerativeComponents* to discover designerly patterns that could be generalised and applied within the contexts of parametric modelling.

As initially described and employed in the anthropological context by Bronislaw Malinowski, participant observation is an ethnographic data collection method that is also well-established in disciplines other than cultural anthropology, such as sociology, psychology, education and many others (Qian et al., 2010, p. 62; Yavena, 2018). It aims "to develop a holistic understanding of the phenomena under study that is as objective and accurate as possible given the limitations of the method" (DeWALT and DeWALT, 2011, p. 110). Spradley (1980, p. 58) explains participant observation as commonly entailing different degrees of involvement from the researcher. At one end of this spectrum, the researcher can be seen as a *complete participant* – fully embedded in activities and interacting with his informants. At the centre of Spradley's scale of involvement, the researcher is a *moderate participant* in the sense that the "ethnographer seeks to maintain a balance between being an insider and an outsider, between participation and observation" (ibid., p. 60). At the opposite end of this spectrum, the ethnographer can be seen as a *complete observer* of social scenes while also recording their observations.

In the same vein, Robson and McCartan (2016, p. 323) view the role of the ethnographer as someone who seeks "to become some kind of member of the observed group". While this indicates issues with subjectivity and is potentially

criticised for not conforming with scientific research standards, Robson and McCartan (ibid.) suggest that, in the study of people and their context, scientific objectives "can be followed by explaining the meaning of the experiences of the observed through the experiences of the observer". It is only through participation with those involved that we can "interpret" our observations (ibid.).

5. Data collection procedure at RFR

In the initial phases of the study, we carried out several rounds of interviews with the professionals at RFR to obtain an overview of the mechanics of their practice with regard to timing, modes of collaboration and frequency of office meetings to address digital design toolmaking initiatives. Acquiring and analysing this data allowed us not only to develop rapport with our collaborators but also served the scheduling and coordination of our field engagement and its alignment with the academic components of our research project.

Our ethnographic study at RFR encompasses two main activities – first, participation, observation and data acquisition, and second, detailed data analysis. In the first phase, the lead author played two different roles – first, "close to the actors and the course of their actions, intervening and participating in little tasks; and [second], at a greater distance so as to be able to translate and inscribe traces of actions and speech acts" (Yavena, 2018, p. 84). For each *in-situ* ethnographic immersion, the researcher gathered data in the form of extensive field notes, voice recording, texts, photographs, screenshots, digital drawings, codes and scripts. In the following stage, we analysed and transcribed the acquired data to find recurring patterns of collective acts and actions, division of labour, the rhythm of design processes as well as different modes of collaborative activities in support of toolmaking initiatives.

As participant observation involves immersion of the researcher within the observed context, the researcher is exposed to a wide spectrum of information, both physical, virtual, and, potentially both interrelated with one another. Spradley (1980, pp. 81–83) designs an ethnographic matrix that serves as a toolkit to dissect "social situations" encountered over the course of a participant observation study. He proposes "grand tour questions" (general questions, highlighted in blue in Figure 1) and "mini-tour questions" (specific questions) to obtain rich and descriptive accounts of the population and context. Spradley points out nine dimensions to observe and sample during field engagement (ibid.). These include *space*, *actors*, *activities*, *objects*, *acts*, *events*, *time*, *goals*, *feelings*. In our investigation on the social dimension and toolmaking initiatives in applied practice, we adapted Spradley's matrix in an attempt to investigate the interrelationship between each of the abovementioned dimensions, as seen in Figure 1.

	Space	Object *(obj.)*	Act	Activity *(actv)*	Event *(evt)*	Time	Actor	Goal/ Objective *(g/o)*	Feeling
Space	**Where do t/m occur?**	Where are *obj.* for t/m located?	Where do acts for t/m occur?	Where do *actv* for t/m occur?	Where t/m *evt* occur?	When are spaces changed for t/m?	Where do actors work on t/m?	Where are t/m *g/o* sought and achieved?	Where do actors express feelings?
Object *(obj.)*		**What *obj.* are used for t/m?**	How *obj.* are used in t/m?	How *obj.* are used in t/m *actv*?	How *obj.* are used in t/m *evt*?	When are *obj.* used?	Who uses *obj.* for t/m?	How obj. are used in seeking *g/o*?	How *obj.* affect feelings?
Act			**What are the t/m acts?**	How acts affect t/m *actv*?	How *evt* affect t/m acts?	How t/m acts change over time?	How actors act for t/m?	How acts affect t/m *g/o*?	How acts affect feelings?
Activity *(actv)*				**What *actv* contribute to t/m?**	How *evt* affect t/m *actv*?	How t/m *actv* unfold over time?	Who are involved in t/m *actv*?	How *actv* affect *g/o*?	How *actv* affect feelings?
Event *(evt)*					**What *evt* contribute to t/m?**	How *evt* for t/m unfold over time?	Who are invloved in t/m *evt*?	How *evt* affect g/o?	What are the feelings in t/m *evt*?
Time						**What are the time periods for t/m?**	When do actors collaborate for t/m?	When are *g/o* archieved?	When are feelings evoked?
Actor							**Who are the actors involved in t/m?**	How do actors achieve *g/o*?	What are the feelings of actors during t/m?
Goal/ Objective *(g/o)*								**What are the *g/o*?**	How *g/o* affect feelings?
Feeling									**What are the feelings during t/m?**

Note: t/m refers to toolmaking processes

Figure 1. Ethnographic Toolkit. Image adapted from Spradley (1980, pp. 82–83).

6. Insights gained and future work

Over the course of our ethnographic pilot study, we gained several key insights pertaining to, on the one hand, day-to-day practice-based collaboration and on the other, the challenges concomitant with participant observation as a qualitative research method in the CAAD world. Firstly, we noticed that the purity of existing, post-rationalised and outcome-focused research is not quite similar to what the lead author encountered and experienced at RFR. As mentioned in Section 2.4, Kvan (2000, pp. 410–412) observes two modes of design collaborative systems within and across AEC teams – *close-coupled collaboration* and *loose-coupled co-operation* (see left side of Figure 2). Throughout our investigation, we observed that architects and engineers not only engage in loose-coupled co-operation but also close-coupled collaboration depending on the development and delivery time of projects. For instance, during the deadline period for one of *Tai Ping Qiao Roof Gallery's* design development phase, Florian and Wanning engaged in a close-coupled design process rather than a loose-coupled one. We hypothesise this observation as to ensure proper and productive communication and sharing of data between them as well as to meet all the delivery outcomes and requirements. Likewise, each of our industry informants collaborates in small groups on several projects (usually between 2 and 4) running in parallel, *de facto* implying the presence of mixed-mode collaborative design processes at the office (see right side Figure 2). In an interview with Florian, he revealed that knowledge sharing and data reuse between projects are desired targets to increase productivity.

Contrary to popular belief regarding the difficulties to reuse parametric models (Davis, 2013, p. 45), we noticed that our professional collaborators at RFR tend not to discard codes and scripts but, instead, archive and share them through a virtual library running on the office network system. Florian seeks to generalise his codes and scripts as much as possible in an endeavour to share them with colleagues who might not possess as much scripting expertise as well as for future reuse to support projects of similar kinds.

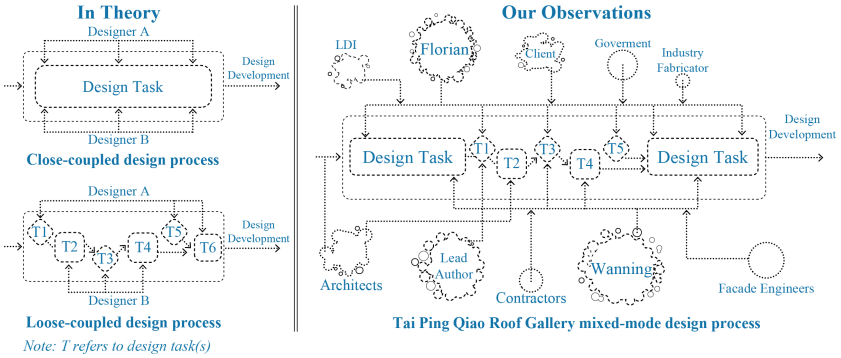

Figure 2. Left side: Collaborative activities in theory (adapted from Kvan, 2000). Right side: Collaborative activities in practice.

We encountered some challenges associated with participant observation. These challenges concern: striking a balance between academia and practice; the researcher's intended role at the office; staff retention and challenges beyond our agency. Initiating an ethnographic study in advanced practice, required numerous background processes prior to the start of the field investigation. While these involved multiple formalities such as ethics and consent approvals, one of the primary trade-offs was to find an alignment between the timeline of the academic research with the project schedule of our collaborators. For instance, by the time we were able to launch our investigation at RFR, the *Tai Ping Qiao Roof Gallery* project had already begun and passed some milestones in the design development phase. Secondly, we encountered a social challenge inherent to collaborative practice as we saw a change in the lead author's expected role at RFR. Entering the engagement with a particular understanding of his role, he saw his role change during the participant observation study. He expected to collaborate in support of design toolmaking initiatives with Florian and Wanning, but *de facto* found himself co-operating with them. We formulated several hypothetical explanations for this experience. This shift may have been: (1) an effect of the sitting order in the office since, due to space limitations, the lead author did not work at the same table as his industry colleagues, (2) a consequence of his experience in using digital design tools, which may have suggested that he can work autonomously. In future investigations, we are determined to engage over more extended periods of enquiry to explore and gain a better understanding of these socially-driven collaborative activities in practice – processes that we understand to be critically important and which may not be readily explicit.

We found Spradley's (1980, pp. 81–83) ethnographic matrix a valuable tool within and across the digital design field. Despite demanding significant time and rigour "to be able to translate and inscribe traces of actions and speech acts" (Yavena, 2018, p. 84) of our informants, however, we could not fully explore our adapted ethnographic toolkit in our six weeks of fieldwork. The reasons for this are twofold. Firstly, we witnessed an unexpected level of staff movement during our practice engagement. One of the firm's leading talents and our key informant changed the nature of his contract with the company and decided to launch his own start-up practice. While this should be acknowledged as a feature of ethnographic research, within the time scope of our study, it effectively became an impedance to our investigation. Secondly, around the same time, the COVID-19 pandemic restricted people's movement. It changed the nature of collaborative work in practice and severely limited the possibility of academic fieldwork. In future studies along this avenue, we intend to carefully consider to what extent the nine dimensions of the toolkit may need to be adapted to particular social and practical contexts while remaining open to unpredictable economic, social, environmental, and political events.

7. Conclusion

As others have pointed out, the inadequacies of standard CAD packages have prompted the increased use of parametric modelling systems while also encouraging the emerging scripting culture among practitioners in the field. In advanced architecture and engineering practices, multidisciplinary teams comprising architects, engineers, consultants and other experts are orchestrated to collaborate on a day-to-day basis in support of project-specific digital design tools (Altintas et al., 2019, pp. 333–334; Fischer, 2008, p. 4). While previous reports on digital design toolmaking have a propensity to be post-rationalised and outcome-focused, we presented in this paper a short-term ethnographic enquiry that sheds light on how in-house project-specific tools are crafted within applied design practice at RFR Shanghai.

Throughout our participant-observer study, we gained key insights that fall in two categories – day-to-day practice-based collaboration, and participant observation as a qualitative research method. In theory, it is often understood that designers engage in loose-coupled design processes rather than close-coupled ones. However, depending on our projects' schedule, we observed that our collaborators at RFR employ a mixed-mode collaborative practice which we assume serves to increase productivity during deadline periods. Despite frequent references to the challenges of reusing and sharing codes and scripts, our informants maintain a shared repertoire of generalised digital tools to address future and recurring design challenges.

One of the early issues we encountered was a challenge to coordinate between academic research and practice-based enquiry. In our view, this entails numerous uncertainties that can impact prospective investigations during critical design phases. We also noticed that collaboration in practice is socially-driven and may not be readily explicit to record and analyse. In future studies in this direction, Spradley's ethnographic matrix is expected to serve as a valuable tool to decipher

the mechanics of these social processes. Finally, we reported some challenges beyond our agency that are associated with participant observation. We believe that the CAAD research and design field has an under-utilised need and potential for ethnographic enquiry of this kind, offering opportunities to engage and to better understand design practices in their full richness.

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