ABSTRACT

The question that prompted this research was, “Which variables affect the adoption of new technologies in the schematic phase of the architectural design process?” (Figure 1). Data gathered through an online questionnaire from sixty-two architects and architecture students revealed a number of insights in relation to how the participants currently use technology in their design projects. The analysis of the quantitative data indicates that there is a direct relationship between the age group and the perceived usefulness of the design software. Surprisingly, however, the ease of use was similar across all age groups. The analysis of qualitative data collected in the survey provided insights in regards to why a specific group of respondents perceived their software tools as easy to use, yet not necessarily useful. The paper presents recommendations for future development of design software and technology-oriented tools that wish to incorporate the new paradigms of human-computer interaction (HCI).
INTRODUCTION

The research presented in this paper started with the goal to provide empirical data to support anecdotal evidence of the struggle to accept technology in the architecture, engineering, and construction (AEC) industry. There is a practical relationship between a company’s performance in the architecture practice and the use of technology. The AEC industry has had problems with productivity for over thirty years (Rivera and van der Meulen, 2013), and has been losing millions due to problems in relation to studio culture, business strategies, and technology integration problems (Gallagher and Chapman, 2004). These technology-related problems can vary widely from measuring the company’s return of investment (ROI) to determining efficient ways to integrate technology with their current practice. It is with these issues in mind that this research targets the role of new interactive technologies for the design intent communication, in the interest of improving efficiency in the schematic design phase of the design process.

Because of the business nature of architecture firms, and due to clients’ increasing expectations for better and faster design outcomes, young architects may not be able to spend time exploring and applying some of the digital tools that they learned in their university courses. In comparison to the commercial environment, in academia there is a different kind of pressure for architects to produce a final product. Both environments may be similar, in regards to the process towards a good design. There is, however, one main difference: in the academic environment, the younger generation of architects are more technology-oriented (Szalapaj, 2014). Using an online questionnaire we collected data from architects and architecture students to help us understand whether and to what extent technology affinity affects the adoption of new technology in the schematic design process.

SCHEMATIC DESIGN COMPUTING

In recent years, the architectural design practice has witnessed a change in the use of technology, from the important yet tedious Computer Aided Design (CAD) drafting of construction documents, to using digital tools to explore new design possibilities. Some of the changes in technology usage include: the use of programming graphical interfaces to create and control 3D models, rapid prototyping, tangible user interfaces, and the use of 3D models by fabricators. Current trends of technology indicate that the new generation of architects is very likely to “speak” digital technology as their main language, and design as a second language. It is important to clarify that by no means is the previous statement implying that computational tools will replace the creative design thinking process. Instead, it suggests that the next generation of architects will be comfortable enough with their digital tools so that technology will be at the core of the conceptualisation process. It can be expected that these digital architects will already be digital natives (Jones et al., 2010), capable of not only using new technology but also of manipulating and moulding these tools to meet their needs.

In his book, Szalapaj (2014) studies the effect of the digital generation in contemporary architecture. His work helps to ground the idea of an emerging generation of young architects, who are currently expecting ubiquitous computing in their daily lives. Szalapaj introduces the concept of a generation that views technology as an enabler rather than a disabler; technologies that will help them to create, realize, and communicate their ideas. The fact that they grow up surrounded by technology means that by the time they start learning about design, they will be very familiar with digital technology, and probably programming, to some extent.

There is a large body of work on the previously mentioned topics (Johnson et al., 2009, Szalapaj, 2014, Tang, Lee, and Gero, 2011). To complement this existing research this paper will focus on the relationship of two factors: the imminent computational shift towards new (ubiquitous) technology and the use or non-use of that new technology in the early stages of schematic design.

The literature context will be established by investigating two different aspects of new computing technology,1 sketching and computing, and new paradigms for human-computer interaction (HCI) and their use in the architectural design process.

SKETCHING AND COMPUTING

Architects use sketching and diagramming in their design process to perform functional reasoning, formal arrangements, analogy transfer, structure mapping, and knowledge acquisition (Do, 2002). In the schematic design phase of the design process it becomes almost mandatory to use sketching to convey their ideas. When talking about sketching, Lawson (1994) depicts the relevance of the “unique” hand-brain connection and how it affects the design process. Once again, various authors explore different methods and levels of complexity by which the computer can be integrated into the early schematic design process, not just as a digital pen, but as a medium. Asanowicz (2002) explains, from a historical perspective, the reasons why the development of new methods for digitally supporting sketches was terminated. The lack of graphic representation, typically used by architects in the schematic design phase, prompted some to name the computer as an “incompatible pencil” (Asanowicz, 2002). This section has a quick glance at some of the studies done as part of the renewed efforts to introduce computing in the schematic design phase of the architectural design process.
In their research Broil et al. (2004) introduce ARTHUR as their solution to the limitations of paper-based sketches in collaborative architectural design. The ARTHUR system is an Augmented Reality (AR) enhanced round table that supports complex design and planning decisions for architects.

As an approach to capture a designer’s thought process in sketches, Do (2002) proposes a framework for reasoning that is represented with drawing marks, acts, and reacts. This study illustrates the possibility of developing design support tools based on these concepts. Along with the findings, the author provides a satisfying answer to the question: “why should computer systems support sketching?” Her answer elaborates on the advantages and future use of computer-based sketching environments. Her argument explains that a computational sketching environment should offer additional methods to the traditional pen and paper, such as editing, line reshaping, grouping, duplicating, while maintaining the unstructured feel, affordability, and freedom of traditional media.

In his thesis, Elliott (2002) uses ethnographic studies of how architects work during the schematic design phase and describes the prototyping and evaluation of digital interfaces to support these practices. Two projects examine affordances of digital devices for sketching and a prototype image search interface to support the browsing of architectural images. The enthusiasm of the architects participating in the projects led the author to believe that there is potential for computational support to be helpful during the early phase of design. More than forty years ago, one of the pioneers in this field of research, Negroponte (1973) worked on a sketch recognition experiment. It is really interesting that, while limited by the existing technology, the author was facing some of the same problems that linger in the HCI field today. Two years later, Negroponte (1975) studied the context of the schematic sketch in architecture in relation to computer recognition. Negroponte specifies that his experiment is to be considered a starting point, a mechanism that will lead to conversations between the user and the machine rather than as a means of generating house plans.

NEW PARADIGMS FOR HUMAN-COMPUTER INTERACTION (HCI)

Mark Weiser coined the term Ubiquitous Computing (ubicomp) in the late 1990s (Weiser, 1999). Since then, the world has witnessed an exponential growth of technology, yet ubicomp technology is still taking baby steps in the long path towards full integration into the architectural design process. In the last twenty years, many researchers have made considerable contributions towards design computing and other areas of technology, some of which have slowly made their way into the Architecture, Engineering, and Construction (AEC) industry. In a study of designers in the early phases of a design process, Kim and Maher (2006) indicated that tangible user interfaces have an effect on designers’ behaviour and encourage creative thinking. Hsiao and Johnson (2011) worked on various efforts to create tangible interfaces for design processes. Kim and Maher (2005) presented TULs and Augmented Reality (AR) as offering an alternative to standard keyboard and mouse interaction. The question then arises: how long will it be until this relatively new technology reaches the AEC industry? This paper addresses this question exclusively from an architectural design perspective.
Over fifteen years ago, Van Dam (1997) wrote, “Raster graphics-based networked workstations and ‘point and click’ WIMP GUIs (Graphical User Interfaces based on Windows, Icons, Menus, and a Pointing device, typically a mouse) are the legacy of Xerox PARC that we’re still using today”. Yet, the majority of computer users would still agree that the predominant interface for the last two decades has been the Graphical User Interface (George and Blake, 2010).

However, the dawning ubiquitous computing era is indeed changing Xerox PARC’s legacy. In 2010 George and Blake (2010) introduced Objects, Containers, Gestures, and Manipulations (OCGM, pronounced like Occam’s razor) as the “universal foundational metaphors of Natural User Interfaces (NUI) paradigm”. They claim that their proposed OCGM “provides a pattern that will lead designers and developers to create more natural interfaces, while being flexible enough to support the implementation of context- and content-appropriate concrete metaphors.” (George and Blake, 2010)

The flexible nature of OCGM is what this research seeks to encourage. If the main goal is to better understand how to integrate new technology with a complex design process, then it makes sense to use the latest NUIs metaphors to try to achieve it. Tomitsch (2003) summarises this idea well by stating that: “people who did not necessarily have to work on desktops before were forced to do so due to the advent of desktop computers. New technologies like the wireless local network area protocol allow us again to move away from our desktops.” He also specifies that this is not to be confused as a motivation to just provide people with a laptop, after all the idea is to get people closer to a natural interaction with computers, which may not necessarily involve the desktop WIMP paradigm.

If the next generation of design-related software and digital tools is going to fully integrate with the new era of computers, then these new HCI paradigms will need to be carefully considered. Otherwise there may be a discrepancy between what the new generation of architects expect from technology and what their interfaces and digital tools look like, thus affecting the acceptance, or perceived level of usefulness of the tools.

**SUMMARY**

The previous sections looked at innovative ways to utilise different aspects of technology in the architectural design process. They also looked at the shift towards a new ubiquitous computational era and its associated use of the latest NUI metaphors. However, these works expose a lack of research focusing on the direct application and integration of new technology into the schematic phase of the design process. Despite many possible applications in different areas of design, most researchers take a technology-centric approach, focusing primarily on the software and hardware capabilities of new technology (Abowd and Mynatt, 2000, Friedewald and Raabe, 2011, Koshizuka and Sakamura, 2010, Poslad, 2011), with a few exceptions which investigate design collaboration and spatial cognition applications (Sun et al., 2013, Visser and Maher, 2011). In this work we are taking a user-centric approach by trying to find ways to complement and augment the current design process rather than replacing it with new technology.

By identifying some of the variables that determine the integration of new technology in the design process, this paper provides a first step towards understanding why there is a gap between the availability of new technology for schematic design and its use in practice.

**METHODOLOGY**

Because resistance to change is always a factor in the acceptance of any new technology, the first step was to ask architects how they currently use the new technology available to them. By association, their responses also answer the question whether architects are using technology in their schematic design or not.

The goal was to obtain quantitative and qualitative results from an online questionnaire, which was distributed to architects and architecture students in the United States, Australia, and the Dominican Republic. A link was distributed using social media tools such as LinkedIn and Facebook, as well as through emails and a printed flyer with a QR code.

The online questionnaire was distributed in an effort to better understand how technology is currently being used in the commercial and academic world. The wide variety of participants who completed the online questionnaire allowed us to sample the current levels of acceptance of technology despite their age, level of experience, culture, or other variables that could alter their answers.

**FINDINGS:**

The questionnaire addressed the architects’ perceived level of integration, ease of use, and usefulness of technology in the design process. It also addressed the architects’ familiarity with technology in their offices, studios, classrooms, and other areas.
of their lives. The following chart represents the demographics of the sixty-two participants. (Figure 2) shows that the average age group was thirty-six to forty-five years old.

**QUANTITATIVE DATA**

One of the unexpected results was the fact that the gender in the sampled population was split evenly, fifty–fifty between male and females (thirty-one males and thirty-one females). As a result, the sampled group that responded to the survey is evenly distributed. The gathered data was analysed to help understand the architects’ preferences and compatibility with current technology in both the commercial and the academic environment.

When asked: “which of the following devices do you currently own and use in your daily design process?” 60 per cent responded that they own a Smartphone, with only 23 per cent using that device in their design process. Nearly half (46 per cent) of the participants own a tablet, and 21 per cent use the tablet in their design process (Figure 3).

Surprisingly, only one person owns a Graphic Tablet, but 14 per cent of the participants said they use a Graphic Tablet at work, which confirms the notion that companies are more likely to buy Graphic Tablets to keep at their office, versus an individual purchasing one for their own use.

The majority (69 per cent) of the participants learned only one or two software tools in the last two years (Figure 4). When asked, “what do you think was the hardest part of learning a new software tool?” their responses pointed towards a steep learning curve from the design software as the main deterrent.

Another interesting finding is how late architects begin using their current design software tools: Only 27 per cent use digital tools “whenever [they] start sketching concepts”, while 65 per cent start using digital tools “once the sketches are already clear enough to start developing the design” (Figure 5). This finding corroborates the notion that architects are not accepting of or perceiving as useful, the digital tools available to them for the schematic design phase.

A larger sample may be required in order to generalise this notion within the architecture population, however, this finding helps ground the idea that the schematic design phase is an area with great potential for the integration of new technology.

The initial study question was: “which variables affect the adoption of new technologies in the schematic phase of the architectural design process?” Based on the previously mentioned concept that we are currently seeing a generation of new architects who have a higher affinity for technology than a few generations back, one of the variables that was tested was the age group of the respondents and their perceived usefulness of their current design software in the schematic design process. For the null hypothesis (Ho) it was assumed that there is no relationship between the age group (independent variable) and the usefulness of their design software (dependant variable).
The cross-tabulation (Table 1) displays the demographic characteristics in relation to the perceived usefulness of the design software. The analysis shows a statistically significant relationship between age group and perceived usefulness of the software (chi-square $\chi^2=8.98$, $p<0.05$), such that those who did not perceive the software to be useful tended to belong to older age groups.

There is a need for further study on the relationship between age and perceived usefulness of design software. Because the online questionnaire was distributed to a large number of individuals, the sampled data does not relate exclusively to the new generation of architects. These results are therefore being reported as a pilot study, which will be extended in later studies. The next logical step of this research will be to conduct a series of interviews and experiments focusing on the younger generations of architects, preferably those still in university programs.

### QUALITATIVE DATA

94 per cent of the questionnaire participants found their software useful, while 6 per cent of the participants answered that they do not find their software useful. When asked why, some comments are quite clear: “Not so useful, when you visualise what the new tools can achieve these days”, “Useful? Design software has become mandatory.” Other comments can be quite cryptic: “Not as a design tool. Parametric”. In this last comment it is unclear whether the architect is expecting the tool to be parametric, or that because the tool is parametric he finds it constraining in the schematic phase.

98 per cent of the questionnaire participants found their software easy to use, and when asked “Why do you find it easy to use?” most users accredited it to having used the software for a long time, stating “I have been using it for twenty years”, “I have been using it for so long that it is second nature”, etc.

<table>
<thead>
<tr>
<th>Age: 18-25 years old</th>
<th>Count</th>
<th>Design Software Usefulness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14</td>
<td>Yes 0 24% 0% 23%</td>
</tr>
<tr>
<td>26-35 years old</td>
<td>28</td>
<td>No 0 48% 0% 45%</td>
</tr>
<tr>
<td>36-45 years old</td>
<td>12</td>
<td>Yes 3 21% 75% 24%</td>
</tr>
<tr>
<td>46-55 years old</td>
<td>4</td>
<td>No 1 7% 25% 8%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>58</td>
<td>4 100% 100% 100%</td>
</tr>
</tbody>
</table>

Table 1  Cross-tabulation Chart: Age Group–Design Software Usefulness
This section briefly mentioned some of the comments from the participants about why their software tools were easy to use and why they were useful or not useful. All of the participants who responded negatively to the “usefulness” question were older than twenty-five years. This further emphasises the link between the participants’ responses and the age group, thus connecting these findings with the hypothesis about generational influence in the adoption of technology.

CONCLUSIONS

This paper extends previous findings and indicates a relationship between the age group of architects and their perceived usefulness of design software. The data points to the perceived utility between the age group of architects and their perceived usefulness of design software. The data points to the perceived utility of design software. The data points to the perceived utility of design software.

One of the outcomes of this study is the realisation that the AEC industry, specifically architecture, has an internal shift in the way that technology is perceived at the core of the design process. Computers have been subject to multiple studies across decades where researchers are discovering new technologies, new purposes, and better integration with the design process. Yet the changes that are about to happen in the next decade promise more ubiquitous computing and seamless integration of technology in our social and professional lives. Not only is there a new generation of architects who are significantly more inclined towards technology but also a new computational era, slowly and inevitably connecting to most aspects of our daily life.

Conclusions derived from this research highlight the need to disentangle the concepts of ease of use from usefulness and the importance the age group plays regarding the uptake of new technologies. The new paradigms of human-computer interaction (HCI) are already ubiquitous in our social life and should be incorporated into the next generation of design software and digital tools.

NOTES


2. The term “usefulness” in this paper follows the definition used by Davis (1989) Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS quarterly:319-340; “the degree to which a person believes that using a particular system would enhance his or her job performance”.

REFERENCES


Elliott, Anie Marie. 2002. Computational support for sketching and image sorting during the early phase of architectural design, University of California, Berkeley.


IMAGE CREDITS

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