DECISIONS WE SHOULD PUT IN THE ALGORITHM

Mapping architects' attitudes towards computational and AI-powered tools for practice

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Abstract. Artificial intelligence has gained widespread popularity both inside the profession and outside of it. Much work has gone into creating new tools for AI-powered workflows which can go into architectural design, yet the field of architectural computing has focused less on attitudes that practising architects have towards these tools. In this article, we present a qualitative analysis of interviews with eight practising architects on their understanding, use of and attitudes towards AI for architectural practice. We structure our findings in three categories: ***matters of fact*** (how architects use technology now, and their use and understanding of AI tools), ***matters of concern*** (what participants view as problematic in terms of AI-powered tools for design) and ***matters of time*** (how the future of the profession is seen and imagined). Participants believe their work has gained vastly from digitalization in terms of speed, precision, communication across disciplines and with clients, and simply designing things that were impossible before. There are however also perceived limitations on creative expression imposed by technological tools, a sense of anxiety about keeping up to date in a constantly shifting technological landscape, and a serious lack of trust, expressed by all participants, in AI-powered systems.

Keywords. Artificial Intelligence, Machine Learning, Architectural design, Architectural Practice, Digital Construction

1. Introduction

Artificial intelligence (AI) has gained widespread popularity across fields in the last years and has occupied a large place in public discussions as well. In architecture, both Neil Leach (2022) and Phil Bernstein (2022) have described a new age, that of artificial intelligence, theorising on how the role of the architect

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evolves along with technological development. A lot of work has gone into designing new tools and especially new design frameworks making use of AI for architectural design purposes (Brown, 2023), yet fewer studies have focused on how architects understand and relate to this 'new age'.

The term *architectural technology* (Emmitt, 2009) is defined as a discipline that merges artistic, practical, and procedural skills. Traditionally, algorithms and machines were used to automate the practical and procedural aspects of architects' work, constituting two-thirds of the schema. Lately though, AI started being used also in the artistic or creative aspects of architectural design.

In this paper, we investigate how practising architects perceive the emergence of AI tools as it can relate to their work, and what opportunities and challenges they identify regarding these tools. We aim to shed light on the nature of the transformations that arise from digitalization in general and AI in particular for architectural design. We employ semi-structured interviews with eight practising architects and conduct qualitative thematic analysis on them. Methodologically, the work presented here borrows from the field of human-computer interaction, and responds to the call of Vite et al. (2021) to *'bring human-centeredness to technologies for buildings'*.

2. Digital and computational methodologies in architectural design and practice

The dual *digital turns* in architecture, as elucidated by Carpo (2013, 2017), have fundamentally reshaped architectural design workflows across various phases, encompassing conceptualization, representation, construction, and evaluation. In this transformative landscape, artificial intelligence (AI) emerges as a versatile tool applicable to diverse design challenges in each phase. The intersection of machines and creativity in architectural design has been contemplated by Hansmeyer (2017), who advocates viewing machines as muses, design partners, or tools extending imaginative capacities. Steinfield (2021) categorises machine learning tools in design, art, and architecture as *actors* (co-designing with humans), *materials* (generating novel design material curated by designers), and *provocateurs* (stimulating new ideas). Tamke et al. (2018) suggest a pivot toward machine learning approaches in contemporary architectural design practices to harness data-rich environments. This paradigm shift is evident in the integration of machine learning algorithms into tools for architectural, civil, and environmental engineering applications, expanding beyond conventional data analysis. Examples include the utilisation of Deep Neural Networks for conceptual designs by As et al. (2018), Yang et al. (2019), Del Campo et al. (2020), and Palamas (2022), signalling a shift towards creative domains within the architectural domain.

Within the expansive domain of Human-Computer Interaction (HCI), scholars advocate for infusing a *'human-centeredness'* into technologies for buildings (Vite et al., 2021) and for forging connections between HCI and Architecture (Alavi et al., 2019). These endeavours are recognized as essential components in the challenging task of rendering technology useful for architecture, engineering, and construction teams (Dossick et al., 2019). Notably, there is a paucity of research

specifically addressing architects' experiences with the technological tools integral to their design processes (Møller et al., 2017). Architects' engagement with digital technologies in design unfolds as a socio-technical process, necessitating a comprehensive exploration into how architects and other building design specialists navigate, adapt, utilise, misuse, and potentially resist technological tools. Such an investigation is pivotal for understanding technology's impact on architectural practice and for guiding the development of future tools aligned with professionals' needs in building and construction work. Addressing this research gap contributes significantly to broader discussions on the ethical, social, and professional implications of socio-technical constructs in architecture.

3. Materials and methods

In order to gain a better understanding of how architects feel about the emergence of computational methodologies and especially AI-powered tools, we conducted semi-structured interviews with eight practitioners. In the interviews, we collected demographic data, and continued with questions about the tools used in their work, as well as reflections on how these tools affect work at all design stages in which they are involved. We also asked participants to reflect on the opportunities and challenges that computational and AI-powered tools could offer for the practice, and on the future of the profession as it relates to technology in general. The interviews lasted between 25 and 40 minutes and were collected between October and December of 2023, by two of the authors. We subsequently carried out a qualitative analysis of the data, where two of the authors spent time getting familiar with the transcribed texts and employed an emergent coding approach (Lazar et al., 2010) to collect and code the answers. After this initial stage, we discussed our individual analyses and through negotiations, we refined emergent codes into a final list of primary themes around which we structure the ***Findings and Discussion*** section.

3.1. PARTICIPANTS

In total, eight participants, with 5 to 15 years of education, were interviewed, representing diverse backgrounds from six European countries. This sample offers a comprehensive snapshot of architects' opinions and experiences with various technologies and AI-powered tools across both developed and developing countries. Participants, aged 27 to 37, with varying educational levels (MScs to PhDs) and experience (2 to 17 years), practised in companies of different sizes, providing a nuanced perspective on technology in architecture (see Figure 1). All participants, being relatively young, have used software tools since the inception of their education and possess proficiency in a wide range of software families.

4. Findings and discussion

The participants provide diverse reflections on the potentials, limitations and challenges of computational tools and AI-powered frameworks for architecture. We structure this section in three subsections, based on the themes we identified

in our analysis: ***matters of fact*** (how the respondents use technologies now, and where they feel that their work could be made more efficient through automation), ***matters of concern*** (what participants worry about in relation to technology and AI-powered frameworks), and ***matters of time*** (how the future of the profession is seen or imagined).

ID	Years of practice	Years of education	Countries where active	Size of office	Education Level & School	Computational tools
P1	12	6	Romania	1	BSc & MSc in Architecture, Technical University of Cluj-Napoca (RO)	Allplan, ArchiCAD, SketchUp, Photoshop, Chat-GPT
P2	12	15	Romania	5-15	BSc,MSc & PhD in Architecture, Technical University of Cluj-Napoca (RO)	Allplan, ArchiCAD, Artlantis, Lumion, Photoshop, Illustrator, Chat-GPT
P3	7	5	Czech Republic	5-10	BSc & MSc in Architecture, Democritus University of Thrace (GR)	AutoCAD, Revit, SketchUp, Enscape, V-ray, Photoshop, InDesign
P4	2	6	Denmark	5-750	BSc & MSc in Architecture, Aristotle University of Thessaloniki (GR)	AutoCAD, Rhinoceros, V-ray, Adobe Suite, 3D Scans, AR/VR, Chat-GPT
P5	4	7	Denmark, Greece	5-750	•BSc & MSc in Architecture, Aristotle University of Thessaloniki(GR) •Advanced MSc in Architecture, Bartlett School of Architecture (UK)	Revit, Rhinoceros, Adobe Suite, VR, Grasshopper, Coding in C# & Python, AI models, Chat-GPT
P6	17	6	Portugal, Denmark	5-150	BSc & MSc in Architecture, Luzia University (POR)	AutoCAD, ArchiCAD
P7	5	7	Greece	3-10	• BSc & MSc in Architecture, Democritus University (GR) • MSc in Architecture, National Technical School of Athens (GR)	ArchiCAD, Adobe Suite, Lumion, Chat-GPT
P8	3	10	Greece, Denmark, Spain	1-20	• BSc & MSc in Architecture, Aristotle University of Thessaloniki (GR) • Advanced MSc, IAAC (SP) • PhD in Architecture, Technical School of Valencia (SP)	AutoCAD, Revit, Rhinoceros, Adobe Suite, Chat-GPT

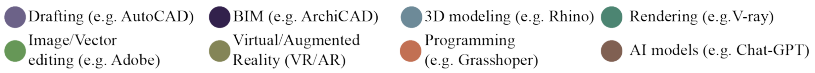

Figure 1. Participants taking part in the interview.

4.1 MATTERS OF FACT

In general, respondents are open to trying AI-powered tools for architectural design, want to keep up-to-date with technological developments, and see whether these could be useful: *'I am open to discover what AI tools could do to help me in my work. I feel that I am unproductive in many ways and I am looking to improve my efficiency: to work better, and faster.'* (P1). All of the participants had some knowledge on AI, and only one did not experiment explicitly with any AI-powered tools at the moment we interviewed them. One of the respondents (sometimes) designs machine learning systems that are later used in a large architectural practice, and reports using ChatGPT also as help when programming, while the others experimented with image generators such as MidJourney as well as with language models, and tried them out for example to help in ideating for a new name for a company, to help with academic writing, or

to generate images about *'this idea in our mind'* (P4).

4.1.1. How technology enhances architects' work currently

All of the participants note that digitalization has changed architectural practice for the better, helping with productivity and efficiency: *'It is much faster to produce designs. [...] because now everything is in sync.'* (P7) and in terms of communication across fields and with clients: *'It greatly improves the perception the customer has of what will be built.'* (P7). It also helps to design things which are impossible to conceptualise without the use of technologies: *'It's more than a tool [...] it's a collaborative relationship. [...] You can have a complex understanding that takes into account several dimensions of reality, which would be almost impossible without this tool.'* (P8)

4.1.2. Workflows across company sizes

The participants we interviewed worked in companies of different sizes: from one-person practices, small to medium companies, to one of the largest worldwide.

The workflows employed across companies vary: **small, one-person companies** report issues related to productivity due to a lack of coordination in softwares used by architects, structural and building services engineers. Here, prices of software packages determine the choices of softwares to be used, although these choices will have long-term impacts on work productivity: '*Unfortunately we don't work on a shared model, no.* [...] *'So there is no coordination. Everyone works with their own software'.* (P1)

Medium-scale companies report currently transitioning from CAD to BIM, or have recently done so, and describe challenges in this re-tooling, but also opportunities. Both small and medium-scale companies report working with BIM immediately after conducting initial hand-sketches: *'I have a few years of experience in an architectural office that was working with [...] ArchiCAD. [...] We had a system for teamwork [...] in time slots (each profession contributed to the shared model at different times).'*(P2) On the other hand, within the same company, there will be different levels of digital literacy, generally with an age-gap divide: *'Compatibility is one of the problems it means like when you have a colleague who is older than you, and he doesn't use the same software as you do, this can make some complications on your work.'* (P3)

Large companies (that are considered at the forefront of architectural design) have dedicated units for computational design and employ a series of extra steps in the conceptual design phase, before they start using BIM tools: *'Our common workflow in the design teams includes Rhino in the early phases, and later Revit to make BIM models. In my department, we are the R&D, we use a lot of Grasshopper scripts, but we're also creating our own tools in C# or Python. Either integrated into Rhino as tools within the design software, or as web interfaces, or even standalone interfaces, depending on what we need to do. In this tool development, we're also using API's from other tools, such as Coco, or any other kinds of API's and libraries we need and [...] sometimes game engines for interactive/immersive experiences.'* (P5).

4.1.3. *On missing tools for automating architectural design work*

Additionally, participants mention places where they consider their workflows to be slow, inefficient or tedious, as follows.

Visualisations remain time consuming, but technology makes a big difference in mediating communication: '*I gave as an input one of my own renderings and it transformed it in a very kitschy way.* (P1)

Detailing is complex, difficult and inefficient and AI-powered tools could help to automate part of this work. Of the architects we interviewed that are involved in architectural detailing, they note that: *'It would be great if you would just go in 3D, select a corner, and say: have this detail here.'* (P1). Similar ideas are also noted by P6: *'Detailing is the most complex part of architecture. ArchiCAD - gives me a base of detailing, it's good, that gives you that option to edit [...] but I hope that in future it will be easier to do.'* (P6)

4.2. MATTERS OF CONCERN

The article *"Speculative Hybrids"* (Pouliou et al., 2022) investigates architects' understandings regarding technological tools shaping architectural practice, categorising concerns into design processes and ethical sustainability issues. Regarding design, architects express concerns about software rigidity enforcing specific thinking patterns and the extended gap between ideas and representation. Ethical and sustainability challenges involve computational tools simplifying societal issues into numerical formats, expensive computational resources, and limited accessibility to education on emerging technologies. In our interviews, participants echo some of these concerns and add categories related to (1) ***limits on creative expression***, (2) a ***sense of technological overload or malaise***, a general (3) ***anxiety about keeping up to date*** and a generalised (4) ***lack of trust in AI*** and regulations related to it.

4.2.1. Limits on creative expression

Half of the participants mention they feel that software tools and technology in general limits their ability for creative expression, although those who mention this refer specifically to BIM tools: *'These software (Archicad and Allplan) were limiting in terms of design, capabilities, and exploration.* (P2) or [about Archicad] *'It still limits your imagination for new things.'* (P6) and [about technological tools] *'in the end, it might inhibit creativity sometimes'* (P8). This is similar to what P7 states: *'Depending on what each software can produce, you end up doing this much, there is a limit which I consider very bad.'*

4.2.2. Technological malaise: 'Technology steals something from us' (P2)

Moreover, some even feel that extensive use of technology is detrimental to individual thinking, and could hinder architects from using their own intuition: *'I feel that we start using our brain less and less [...] we want to make it easy and comfortable, and become lazy. When you write and you want to express your own architectural idea, you're the only person that can express it, I really don't know how a machine can express it instead of you. I consider it [technology] only as a*

negative thing in these terms.' (P3) or: *'We are spending a lot of time on technology and we are not so aware of our natural intelligence.'* (P2), and: *'AutoCAD is a piece of paper [...] and it's very honest to us. So if you draw it wrong, it's wrong [...] you have to draw every single thing, it means you have to think about every single thing'* (P6) this explaining that with BIM software, since some elements are readily available, one is tricked into thinking less about certain details (especially construction details or problems) that could come up.

All these represent a certain technological malaise, or overload, and to some extent even a sense of nostalgia for a time when architects had fewer tools to enhance their work processes.

4.2.3. The anxiety of keeping up to date

Many of the participants express a certain anxiety about having to keep up with emerging technologies and report difficulties in finding the time to invest in learning (yet) another piece of software while balancing this with an active career as an architectural practitioner: *'[about collaboration in BIM] I have not learned or used these tools in my work as my projects are smaller. I simply did not consider that it was worth it to invest the time in learning to use these tools'* (P1) or *'I feel that it keeps you in some chasing game that you need to learn more and more all the time, you have to keep up all the time.'* (P3)

Nevertheless, participants feel they should continue learning throughout their careers *'it is hard because everything grows so fast, that it's hard to keep up - but we should try.'* (P4) and *'I think it's necessary to adapt the domain'* (P2).

4.2.4. Trust and regulations

Apart from the concerns expressed above, architects also express issues related to trusting these systems. All eight participants report not trusting AI-powered tools. Most note that if it is not possible to understand why a tool gives certain results, then they do not see how it can be used to support decisions in architectural design: '*I want to follow these technologies and AI just with a critical mind, I wouldn't trust blindly what I get as a result.'* (P4). In addition P8 states: '*I don't trust it [...] many times the answers it gives me have a lot of errors. [...] 'I really feel that it's kind of a black box: I don't know [where] anything is coming from, so I cannot believe or trust its valuation'.*

The experiences of P5 in this case are very interesting, *'it's really important for the process to be transparent. [...] If we know how the scientific methodology behind an algorithm works, then yes, it makes sense to make decisions based on that.' [...].'* Moreover, both the participants working in large companies and those working in universities mention that large corporations (in Europe) do not allow the use of these tools yet because it is not clear how to engage with them given copyright issues: *'where I work - it's a corporate company - we cannot use these platforms because of regulations from the company'* (P4) or '*We are a very traditional education, we do not accept it yet and we don't have the tools to use it. We don't know how to incorporate it because of the plagiarism issues that surround it.'* (P2). Additionally, P5 mentions: *'We cannot use tools of which we*

are not 100% sure. We cannot go to the client with a number and not explain this number.'

Perhaps most importantly, participants note that they feel they would like to be educated about how AI works, and that having a better understanding of the ways in which these tools make decisions, would allow them to trust them more. In this way, critical computational thinking is suggested as a subject to be taught both as part of architectural education, but also as courses for life-long learning for professionals: *'If I think about softwares using AI for architecture - I think: ok, but how much input can you give them? How do they generate the final product? And how does that correlate to what you put in the software? So how does it work actually?'* (P1) or *'I'm very curious about exploring - to know how to implement it. Our generation didn't have the chance to experiment with it while studying. So I would love to have a seminar.'* (P8), or: *'What could be done is to educate people better in this matter.'* (P7)

4.3. MATTERS OF TIME

Some of the participants (P1, P2, P3, P6) feel that the profession is becoming increasingly technical, and that the more creative, or artistic aspects of architecture are being neglected. This pressure comes both from the technologies that enforce certain ways of thinking, but also from clients who demand more technical (quantitative) knowledge about the project from the beginning (i.e. wanting to know the carbon footprint, how the building would perform from an energy point of view, or how much it will cost in a very precise way): *'Architecture is becoming extremely complex, with every year that passes, and more technical than it was 15 years ago, which is very demanding for the architects, and sometimes just makes them have less time for the most creative part of it.'* (P6) Overall, P6 believes that AI tools could be useful in two stages of a project *'In the beginning and in the end. At the beginning you need to collect all kinds of information, all the rules, all the considerations that you might be forgetting. [...] In the end, when we get to a very very technical part of the project, it can be a great assistance.'*

When asked to reflect on the future of the profession, P1 states that *'We need to think in a more sophisticated way than to claim that AI will make us lose our jobs. I don't think it is capable of doing something that is of high enough quality.'* P3 adds on this but also discusses who would make most use of such tools: *'You could put information such as size of your plot, what kind of house you want to have, and your style (pictures from Pinterest), and then it produces drawings for you: renders and mood boards. I'm not sure if this is going to be implemented from the architect side, or from the investor side [...] Because, it's so much cheaper for them.'* (P3)

P6 and P7 hope that AI-powered frameworks would assist in the more tedious activities but not interfere with the creative exploration: *'I believe that these tools could be very good if they can give you assistance in the technical parts of projects, I would prefer that to don't interfere with that much on the creative part.'* (P6) and: *'To give the AI a model that I build myself, and tell the system: I want*

views, sections and these changes on the design. In other words, do all the hard tasks I don't want to do because I'm bored doing it.' (P7).

5. Conclusion

This research delves into architects' perspectives on computational methodologies and AI-powered tools, revealing a nuanced landscape marked by a range of enthusiasm and scepticism. Architects acknowledge the transformative impact of digitalization on their profession, emphasising improvements in speed, precision, interdisciplinary communication, and the realisation of previously unattainable designs. However, concerns emerge along three thematic axes: factual, concerned, and temporal. Participants express a willingness to embrace AI-powered tools for enhanced operational efficiency while acknowledging the limitations, particularly in creative expression.

The perceived rigidity of BIM tools raises concerns about workflow constraints, with practitioners, from individuals to corporate entities, describing heterogeneous approaches. Challenges persist during transitions from CAD to BIM, with a demand for tools automating simulations, visualisations, and detailing, presenting opportunities for AI frameworks. Concerns centre on the impact of technology on creative autonomy, with fears of constraints and overreliance eroding individual ideation. Anxiety lingers about adapting to rapidly evolving technologies, emphasising the perpetual learning curve in this technology-driven profession. Architects harbour mistrust in opaque AI decision-making algorithms, posing ethical and professional challenges. Architects envision a future where technical proficiency integrates with expressive creativity. They approach AI judiciously, emphasising transparency in processes and recognizing the need for education to deepen their understanding of AI. The discourse underscores the delicate balance between maximising efficiency and upholding foundational values like creative expression, ethics, and professionalism. The ongoing interaction between architects and evolving technology is poised to significantly shape the trajectory of architectural practice in the coming years.

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