Lost in Architectural Designing: Possible cognitive biases of architects during the early design phases

Jessica Bielski[1], Christoph Langenhan[1], Viktor Eisenstadt[2,3], Frank Petzold[1]

[1] Technical University of Munich, Munich, Germany
jessica.bielski@tum.de; langenhan@tum.de; petzold@tum.de
[2] German Research Center for Artificial Intelligence (DFKI), Kaiserslautern, Germany
[3] University of Hildesheim, Hildesheim, Germany
viktor.eisenstadt@dfki.de

Abstract. In order to meet the housing demands of the future, architects need to work faster and more efficiently while improving architectural quality. The metis projects aim to create an intelligent design assistant supporting architects during the early design stages through suggesting further design steps for spatial layouting, based on the best practice of reference buildings. By enhancing suggestions with explainability, the system offers insight to improve Human-System-Interaction (HSI), bridging the 'black box' problem. The explanations aim to either support the reasoning process or mitigate possible biases of architects, which can be rooted in the heuristic 'System 1', as well as the analytical 'System 2', drawing from the 'dual process model'. Within this paper, we propose our approach to clarify the four main heuristic biases and the logical errors of architects, when using reference buildings, and their respective representation during the architectural design decision-making process.

Keywords: Decision Making, Biases, Explainability, XAI, Human System Interaction

1 Introduction

The world's population is expected to reach the ten billion mark by 2050, for which about two thirds of the population will live in the urban area (United Nations, 2019). In order to meet the increasing demands for residential housing, concerning both quantity and sustainability, architects need to be able to work faster, and more efficiently, while increasing architectural quality. The decisions of the early design stages are of significant importance for satisfying these requirements of a fully constructed building (Harputlugil et al., 2014). The sooner well-informed decisions are made, the higher the quality of the final building. Vice versa, the later fatal flaws are recognised during the architectural design, the more difficult correcting them and changing the design becomes (Buxton, 2007). Thus, the design decisions of the early design stages have a high impact on the duration, architectural quality, and sustainability of the entire building, in terms of design and construction process. Further, efficient design, designing and information management of the early design stages can result in an estimated material waste reduction of 33 percent (Haeusler et al., 2021).

Through adaptation for the workflow of Computer-Aided Architectural Design (CAAD), the methods of intelligent systems are applied to support architects in fulfilling complex tasks of architectural designing and planning. Derived from these principles, the metis projects pursue an intelligent design assistant suggesting further design steps for spatial layouting during the early design stages. In order to propose methods of explainability for such an intelligent system to facilitate more intuitive work and high-quality architecture by the means of Human-Computer-Interaction (HCI), specifically Human-System-Interaction (HSI) methods, we examine the reasoning process of architects for the use of reference buildings, i.e. ‘architectural precedents’ (Richter, 2010). From the inquiry methods and reasoning goals, we derive possible biases and logical errors of architects, using the ‘dual process model’ of the human mind, based on cognitive sciences and psychology (Wang et al., 2019). Within this paper we describe our triangulated approach, using a theoretical literature review and a limited case study, for clarifying the four main heuristic biases (‘representative’, ‘availability’, ‘anchoring’, ‘confirmation’) of pattern-matching ‘System 1’ and logical errors or weaknesses (i.e. ‘misplaced trust’) of analytical ‘System 2’, as well as their respective representations for the use of reference buildings during the early design stages.

2 Related Work

The field of eXplainable Artificial Intelligence (XAI) is a quickly expanding area of research and industry. Barredo Arrieta et al. (2020) aim to define XAI for machine learning (ML) on the backdrop of existing research and findings, as well as its projected future development. Palacio et al. (2021) focus on establishing a consensus and framework for XAI strategies for implementation. Meanwhile, Wang et al. (2019) shift from a view point of performance and system possibilities to an HCI focus, proposing a conceptual framework, initially created for medical diagnoses, to design explainability for any target group and steps for a theory-driven adaptation for a specific user group (see Figure 1).

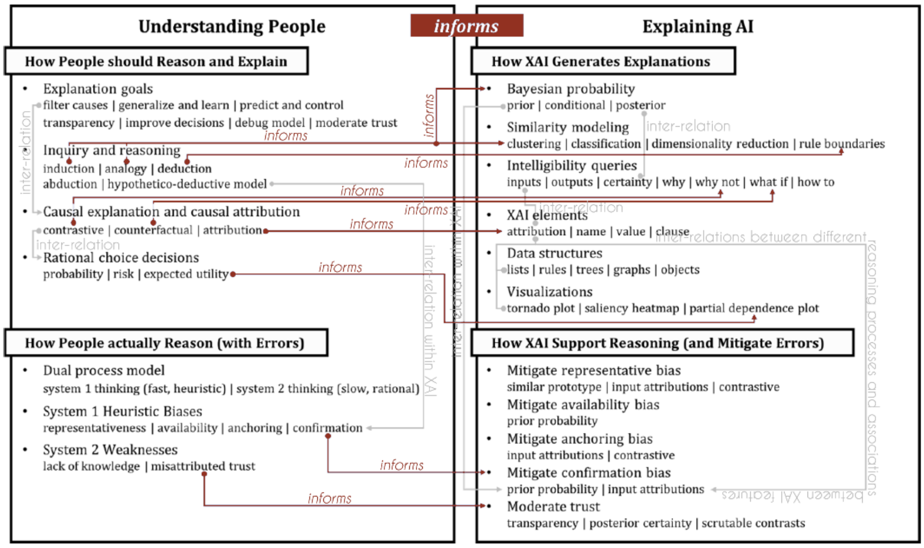

Figure 1. Conceptual framework for reasoned explanations (Adapted from Wang et al., 2019, p. 4).

The framework is divided into the human reasoning process to the left and explainable intelligent system methods to the right. The human reasoning to ‘Understanding People’ on the left-hand side of Figure 1 is separated into ideal reasoning ('should reason') and true human reasoning ('actually reason with errors’) of heuristic ‘System 1’ and analytical ‘System 2’, which inform the corresponding intelligent system facilities to the right for generating explanations as an ‘Explaining AI’. The system answers to both the ideal and true human reasoning with different strategies through either the support of human reasoning or the mitigation of biases of heuristic 'System 1' of *representative* or *representativeness*, *availability*, *anchoring*, and *confirmation*, as well as errors of analytical 'System 2', such as *lack of knowledge* and *misattributed trust*. Wang et al. (2019) summarise the following four steps for adaptation of the framework for a specific target group, based on the respective goals, inherent inquiry methods and best practices:

1. Clarifying the user's reasoning goals through a literature review, ethnography, and/or participatory design
2. Identifying possible biases for the respective applications through a literature review, ethnography, and/or participatory design
3. Deducing appropriate explanation ways for reaching reasoning goals and/or mitigating cognitive biases using the framework’s pathways
4. Integrating the explainable intelligent system facilities to create an explainable user interface

The common practice of architects of using reference buildings (e.g. floor plans and other visualisations), is a well-recognised approach in architectural designing with exemplary designs to be used with originality and for creating innovation (Richter, 2010). Architects utilise these ‘architectural precedents’ as examples to create a basis for their design process: as a source of inspiration, design conditions and explicit information, as a tool for evaluation of their own design, and as a medium for communication (Ibid.). They are synthesised with their mental collection of architectural objects, knowledge from other sources and previous experiences into new original architectural designs using their personal design philosophy, Lawson’s ‘Guiding Principles’ (2005).

In order to deduce the inference and explanation methods, the decision-making process of architects needs to be examined. Rational choice decisions are applied through value-risk-measurement and expected utility. However, due to the highly complex and ill-defined decision-making process because of unique design problems, involved stakeholders, designers and environmental circumstances, the architectural design decision-making process can neither be described as linear, nor standardisable. By assuming the position of Harputlugil et al. (2014), it can be described as an order-less analytical hierarchy process (AHP) with Multi-Criteria Decision-Making (MCDM) to design an individual solution for the unique problem to achieve the best possible quality of architecture. Thus, the design decisions of the early design phases, especially forming and framing the design problem and creating a mental hierarchy of the different criteria, have significant influence on the architectural quality of the final building (Ibid.; Buxton, 2007). The sketching process, a supportive practice to make ideas of the early design stages tangible and to advance design development (Laseau, 2000; Lawson, 2004; Lawson, 2005; Suwa & Tversky, 1997; Lertsithichai, 2005), can be described as a constant back-and-forth of elaboration of ideas into many alternatives or variants and reduction through selecting the most promising solutions or solution aspects (Laseau, 2000; Buxton, 2007).

Aiming to provide the best possible HCI - or HSI - for architects designing during the early design stages, the interface of the architect and the system should assimilate to the best practises of the respective design stage, sketching for the early design stages. Nevertheless, contemporary Computer-Aided Architectural Design (CAAD) tools, as well as their Graphic User Interfaces (GUIs), largely focus on the system possibilities (Lertsithichai, 2005). However, the incorporation of genuine tools and practices, a basis of User-Centred-Design (UCD), facilitates a short learning process and the mitigation of errors of application usage by considering the user’s needs and goals. It improves efficiency and effectiveness of an interactive system (Lee, Chuang & Wu, 2011), especially when considering the design of an intelligent design assistant built on XAI strategies.

3 Approach

Using the methodology of triangulation derived from cognitive sciences, we propose the following approach. The described steps of Wang et al. (2019) are used to adapt their conceptual framework (see Figure 1), created for medical diagnoses, for the specific target group of architects using reference building during the early design stages (see Section Related Work). A literature review is conducted on the workflow, architectural quality, design requirements, design tools and architectural design process (Laseau, 2000; Lawson, 2004; Lawson, 2005; Buxton, 2007; Schön & Wiggins, 1992; Darke, 1979; Harputlugil et al., 2014; Suwa & Tversky, 1997; Negroponte, 1973; Lee, Chuang & Wu, 2011; Lertsithichai, 2005; Richter, 2010) in order to clarify the user's reasoning goals (Step 1), as well as identify possible biases during the process and for supporting intelligent systems (Step 2). This theoretical research is triangulated in Bielski, Langenhan, Ziegler, Eisenstadt, Petzold et al. (2022) through a case study utilising a digital paper prototype, based on the deduced explanation methods and explanation visualisations (Step 3), and implemented as a high-fidelity clickdummy of a hypothetical application of an intelligent design for tablet devices (Step 4). Within this paper, we focus on Steps 1 and 2 for clarifying possible biases of architects, deduced from their inquiry and reasoning methods, as well as explanation goals and methods of architects during the early design stages.

4 Literature Findings

4.1 Inquiry and Reasoning

Based on the formalisation of the architectural design process as an AHP with MCDM, as well as the use of reference buildings, the inquiry methods of architects can be deduced. It is presumed that architects use inductive and analogical reasoning for reference buildings to be a source of inspiration and design conditions, but also as a tool for evaluation of the own design. The AHP-based generation of alternatives, a characteristic of the architectural design process of the early design stages, serves the purpose of applying these reasoning methods to select the most promising solutions or solution aspects.

4.2 Explanation goals and methods

The architectural design decision-making as an MCDM process is supported by contrastive explanations, where architects heavily rely on counterfactual reasoning by using 'What if?' - and its transfactual derivation 'How to?' – for causal chain scenarios of interchanging both criteria or sub-criteria themselves and/or the values of criteria within the AHP (see Table 1). Further, the pair-wise comparison of tangible and intangible, and subjective and objective criteria for highlighting relationships is sought to support contrastive reasoning.

Table 1. General description and description for the architectural design process of explanation methods.

Explanation methods	General Description	Description for Architectural Design
Contrastive	Why? Why not?	Comparison of different architectural designs
Counterfactual	What if?	Exploration of impacts of different architectural designs
Transfactual	How to?	Exploration of goals through different architectural designs

Derived from the explanation goals and methods answering to the inductive and analogical reasoning of architects, possible biases are presented. This includes each of the different heuristic biases, caused by human thinking using quick pattern matching by ‘System 1’, and the weaknesses of slow, logical thinking of ‘System 2’, as defined by Wang et al. (2019). They are individually described in nature and occurrence within the architectural design process and their respective impact, as well as illustrated with an example.

4.3 Heuristic ‘System 1’ Biases

The ‘Representative Bias’, also called the ‘Representativeness Bias’, is misjudging the similarity of the conditions of two or more items and consequently, applying their respective solutions, even though they are not transferable. This kind of bias lets architects misinterpret the design conditions of a reference building to be the same or similar to the project’s. Even though the design conditions differ, non-applicable reference buildings are perceived as a possible source of inspiration. Example: A floor plan from the 1920s, which was built with outdated architectural style, materials and construction technology, is applied as a reference for contemporary residential housing.

The ‘Availability Bias’ is an error of perceiving memorable, unusual and adverse events, objects or solutions as a common outcome. Thus, an architect might perceive certain reference buildings or aspects thereof as highly likely, while it is actually of low probability. Thus, non-applicable reference buildings might be selected as an inspiration or highly uncommon features are integrated. Example: The architect reviews a plan of an extravagant home, where a shower connects the bathroom to the living room. Due to its memorability, the architect integrates this highly uncommon feature into the design of a family home.

A skewed perception of the value of an item, event or feature constitutes the ‘Anchoring Bias’. Assuming the architectural design decision-making process to be an AHP with MCDM, the skewed interpretation of the weight of a criterion leads to the misalignment of priorities. Architects typically identify a preferred design direction - 'anchor' - at the beginning of the process, the *primary generator* (Darke, 1973) around which the design revolves. Focusing on a false 'anchor' causes a chain of misaligned priorities, disrupting the entire architectural design, design process and quality. Further, the anchoring bias can happen in each level of the hierarchy, but the higher the level, the more fatal it is. Example: Within the study of Laseau (2000) post-graduate students often focus on shape of rooms and building, instead of their use and flexibility.

The 'Confirmation Bias' describes the collection of redundant information for confirming a hypothesis instead of evidence for other possibilities. It can occur within the architectural design process, through the review of reference buildings, which solely confirm the pre-conceived design ideas. Consequently, the elaboration process only generates a limited number of variants, no alternatives. The architect neglects to use a variety of reference buildings of the same design conditions as a source of inspiration and tool for evaluation. Example: The architect uses for referencing, as well as evaluating, solely their own previous works and standard floor plans, simply out of habit.

4.4 'System 2' Weaknesses

Misplaced trust is an issue of analytical, logical 'System 2', operating at a slow, but thorough rate. Due to lack of knowledge, information provided by authority figures, or presumed authority figures with larger knowledge, may be assumed to be true without any further research or validation. This is also applicable if the architect has overconfidence in the own abilities.

An intelligent system is created and debugged by humans, mostly computer scientists, generating suggestions based on its data and implemented rules. Thus, it can have flaws, i.e. due to inferior system capabilities, bad coding, and lack of quality or volume of data. The intelligent system may make skewed assumptions, suggesting false further design steps. If the user of such an application has complete trust in the system ('oracle'), all suggestions are presumed correct and applicable without further questioning, especially if the architect has little experience and knowledge. Example: Based on a disproportionate amount of floor plans of the 1980s with enclosed rooms in the database, the system presumes their high probability. Because of an unconditional trust in the system, the inexperienced architects unconditionally accepts the generated suggestion.

4.5 Cognitive Biases of the Architectural Design Process

The previously detailed biases of 'System 1' and 'System 2' have been summarised within Table 2. It consists of the general description of the individual biases, as well as their respective representation within the architectural design decision-making process for the use of reference buildings.

Table 2. General description and description for the architectural design process of heuristic biases of heuristic ‘System 1’ and logical errors of analytical ‘System 2’.

Heuristic Biases	**General Description**	**Description for Architectural Design**
Representative	Misjudging the similarities of two events/objects due to matching unrelated conditions	Misinterpretation of a reference building of different design conditions as a source of inspiration
Availability	Perceiving memorable, unusual or adverse events/objects to be a more likely outcome than they truly are	Perception of a reference building or a certain feature as a source of inspiration due to it memorability, even though it is of low likelihood
Anchoring	Skewed weight of a feature value of an event/object, referred to as ‘anchor’	Skewed perception of the value of a criterion or sub-criterion within the architectural design decision-making process (for AHP with MCDM)
Confirmation	Collecting information to confirm existing hypothesis, instead of different events/objects for same conditions	Collection of redundant references buildings as source of inspiration, even though the design conditions allow for a wider variety
Logical Errors	**General Description**	**Description for Architectural Design**
Misplaced trust	Unquestioned trust in provided information of probability of event/object	Overconfidence in recommendations for reference buildings (e.g. by tool, colleagues, other stakeholders) as a source of inspiration, design conditions and value within architectural design process
Lack of knowledge	Lack of access to situational information, as well as collected knowledge through e.g. experience	Inability of discerning applicability of reference building as a source of inspiration, design conditions and value within architectural design process

5 Study results

As mentioned within the Section Approach, a digital paper prototype, integrating the deduced explanation visualisations in the graphic user interface, (Bielski, Langenhan, Ziegler, Eisenstadt, Petzold et al., 2022) was used within a case study with architects of different backgrounds (from Europe and Asia; approximately 30 years of age) working in Central Europe for three to five years. A digital prototype demonstration is followed by a semi-structured interview, consisting of three question sections: *explanations*, *explanation visualisations* and *user perception*. Based on the expressions of the participants, the first question section is indicates, if and how the implemented explanations could support the reasoning process or mitigate the targeted biases.

It becomes clear that all targeted biases were successfully addressed. However, it was observed that the handling of the individual explanations - the information within the explanation visualisation - determined which biases were mitigated. The same information was used by the architects in different ways and thus, other described biases were additionally addressed, e.g. the multitude of different suggestions on the backdrop of their design conditions targeted the 'Confirmation Bias', but also influenced the 'Anchoring Bias'.

The study participants (P[n]) themselves identified possible biases, which the intelligent design assistant may mitigate. They expressed how the big database and suggestions of an intelligent design assistant could support them in getting rid of '*old habits'* (P2, P5, P8, and P10). Thus, the participants themselves identified the opportunity to overcome the heuristic biases of 'Availability', 'Anchoring' and 'Confirmation' by the means of the support of an intelligent design assistant. P3, P4, P5, P7 and P9 even identified the opportunity to customise the intelligent design assistant through the personal input and requested manual debugging of the floor plans to incorporate specific buildings. They wanted to change, rearrange, add or remove reference buildings for maximised moderation of trust and scrutability to use their knowledge to examine the system and avoid 'Misplaced trust'.

6 Discussion

However, negative effects of the explanations targeted at the biases of the architects could also be observed. P2 expressed insecurity and a deprived ownership over the own design and design decisions due to suggestions of the system introducing a new level of self-awareness and thus, possible biases towards the own design ideas. The presumption of an intelligent design assistant, offering recommendations through AI technology, being an omniscient oracle seemed to mislead some participants into valuing the suggestions of the system higher than designs based on their own knowledge and experience. P4 expressed similar thoughts - even though positively - that they would simply choose the first suggestion of the intelligent design assistant as *'it is an artificial intelligence, it knows what it is doing*'. Nevertheless, most participants found the trust well moderated, based on the 'transparency' of the intelligent design assistant. The insight into the 'black box' mechanisms, e.g. raw data, provided the architects with unexpected opportunities for scrutability. They were excited at the idea of removing, re-arranging the priority of reference buildings, and introducing floor plans of their mental collection into the training data, personalising and debugging the system for original designs.

Finally, the approach needs to be discussed, which is largely based on a theoretical literature review synthesised with the framework by Wang et al. (2019) and use of reference buildings as defined by Richter (2010). The remote case study, using a presentation of the digital paper prototype and semi-structured interview, has a limited number of participants (n=11). As the amount is scientifically insignificant, the case study serves as a pilot study for determining further persuasion of the topic, evaluation of the approach and pointers for future work. Because of the encouraging results, we consider our triangulated approach with the adaption of the framework by Wang et al. (2019) for the identification and mitigation of biases of architects during the early design stages successful and consequently, worth further pursuing.

7 Conclusion and Future Work

By applying the methods of social sciences, like triangulation, we further developed and evaluated our theoretical findings of a literature review of the cognitive reasoning process of architects and their respective biases for the use of reference buildings through a pilot study with working architects. Our results show that architects may present the four heuristic biases of ‘Representative’, ‘Availability’, ‘Anchoring’ and ‘Confirmation’ and the logical error of ‘Misplaced Trust’, while we are able to specify in which way these biases present themselves. Thus, we contribute the basis for creating a design support approach by transferring the theory-driven methods of Wang et al. (2019) to the domain of architecture, by creating theory-driven explanations for architects. Our approach can be further transferred to other design domains. By better understanding the specific user, we facilitate more intuitive work with an intelligent design assistant and consequently, high quality architecture, while speeding up the process and reducing the work-related stress on architects.

In the future, we aim to determine the right timing for explanations and thus, we plan on investigating the temporal aspect of the presented biases during the architectural design process (Bielski, Eisenstadt et al., 2022). In a first step, we analyse the design process by the means of sketch protocol studies (Suwa & Tversky, 1992), as described in Bielski, Mete et al. (2022), segmented into design phases (Lawson, 2004; Laseau, 2000; Barelkowski, 2013), as explored in Bielski, Langenhan, Ziegler, Eisenstadt, Dengel et al. (2022) and Mete et al. (2022). By utilising these findings, we are able to present the information for mitigation of biases at a useful time. Thus, we can reduce the amount of explanations permanently visible for the user to avoid information overload. It enables the user to focus on the design activity, which ultimately assertives the ownership over the own design. By reducing the permanent input of the intelligent design assistant, while highlighting the fallibility of an AI system through scrutability and debugging options, we aim to provide insight into ‘black box’ systems to avoid undisputed acceptance of possibly subpar suggestions.

As mentioned in the beginning, quick, efficient and sustainable work is essential for meeting the future demands on the construction industry. The intelligent design assistant envisioned by the metis projects aims to support the design decision-making through suggestions, enriched with explanations targeting possible biases of the architects of the early design stages. Finally, we hope that our work may inspire and guide future research for supporting architects to design in more informed ways and with more confidence early on to create high quality architecture more efficiently and sustainably.

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