**Title: Visual Communication in AI Chatbots in Architectural Participatory Design**

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**Abstract**

This research proposal aims to address the existing gap in knowledge regarding the utilization of visual communication by AI chatbots in the context of architectural participatory design (PD). Despite the significant role of visual artifacts in architecture and design, current human-AI communication is limited due to the absence of visual communication. This study seeks to invent novel methods and protocols for human-computer interaction within the architectural workflow, enhancing design outcomes and democratizing design processes. The proposed research will investigate textual and visual communication protocols between humans and computers in architectural design, bridging the gap between the current understanding of chatbot design communication and traditional client-architect communication. The goal is to formalize a human-computer communication method that leverages conversational interfaces and image generation capabilities to communicate necessary complex architectural design information effectively. This approach is expected to automate and optimize the information exchange process, creating a more accessible, inclusive, scalable, democratic, and efficient design method and paving the way for new technological innovations in the design field.

# Scientific Background

## Design Process

Since the 1960s, scholarly investigations have focused on conceptualizing design as an organizational and psychological process, establishing design as a distinct discipline (Gregory, 1966; Cross, 1982). Design is widely recognized as a multifaceted process, comparable to an algorithm, composed of diverse components (Gregory, 1966). Initial studies posited that the design process is comprised of three key stages: 1) defining the problem, collecting data, analyzing, and reaching consensus on design requirements; 2) synthesizing the design; and 3) assessing the design's appropriateness to the problem definition (Jones, 1963). Various design process models have been suggested across multiple disciplines, from engineering to business processes (Howard, 2008). Nevertheless, most of these models incorporate similar components as those delineated by Jones (1965), specifically, analysis, synthesis, and evaluation.

The design process is characterized by its iterative nature, a concept that is integral to its function and structure. Simon (1969) posited that the design process is a rational problem-solving method that systematically searches for solutions within a defined solution space. However, Kline (1985) further elaborated on this concept, emphasizing the iterative nature of the design process. This iterative process is necessitated by complex information dependencies, requiring repeated cycles of design work (Smith, 1998). New revisions are generated, evaluated, and either improved upon or discarded through these cycles. This repetitive aspect of the design process forms the foundational structure for developing design process models (Takeda, 1990).

In an alternative conceptualization, the design process is viewed as an exploration rather than a search (Corne, 1994). This perspective posits an evolutionary design process that explores both the solution and problem spaces (Gero, 1996). In this co-evolution model, problem requirements and solution candidates are iteratively developed until a satisfactory fit is achieved. Empirical studies have found the co-evolution valuable model for describing the design process (Maher, 2003; Wiltschnig, 2013; Dorst, 2001).

## The Role of Conversation in the Design Process

Design processes involve visual representations. However, verbal communication is also a pivotal component. This form of communication facilitates the understanding of the needs and constraints of various stakeholders, including clients, contractors, and community representatives (Lawsonn, 1997; Dubberly 2019). It also aids in the negotiation of project requirements (McDonnell 2009). Moreover, intra-team dialogues foster knowledge exchange and the negotiation of innovative ideas, thereby enhancing the collective capabilities of design teams beyond the individual capacities of a single designer (Arias et al. 2000).

Engaging in conversations with end-users and community members aids in making tacit knowledge explicit from the user's perspective, thereby addressing their needs and concerns regarding a design project (Luck 2003). In the initial architectural discussions, clients focus on buildings' familiar functional aspects, and designers aim to identify issues and comprehend the significance of the design to the client (Luck 2006). However, it is crucial to acknowledge its potential challenges and limitations, such as potential misinterpretations and difficulty translating verbal ideas into tangible design elements (Karlgren 2012).

Given these considerations, visual communication can enhance the comprehensibility of the design for non-professionals. Therefore, exploring how artificial intelligence can best communicate such designs is critical.

## Chatbots and the Automation of Conversation

The history of chatbots dates back to the first chatbot, ELIZA developed between 1964 and 1966, which was based on a language model that identified keywords and, following a set of rules, provided a response (Weizenbaum 1983). Over the years, chatbots have evolved significantly, owing to advancements in machine learning and artificial intelligence. There are now three primary types of chatbots: rule-based, retrieval-based, and generative models (Hussain 2019). Rule-based chatbots function based on a predefined set of rules, while retrieval-based chatbots choose responses from a pre-built database. However, both are limited by linguistic knowledge hard-coded into their software (Shawar 2005). Therefore, generative models powered by machine learning techniques have shown the most progress in recent years since these models can construct novel responses, adapting better to various conversational situations.

Overall, building a chatbot that can understand complex conversations and answer appropriately was reported to be a challenging task (Xiao et al. 2020). However, over the last several years, chatbot design has made significant progress (Sameera 2015). Modern chatbots such as Apple's Siri, Amazon's Echo and ChatGPT leverage machine learning techniques to create large language models and web search results to produce meaningful responses.

To date, there are several publicly available language model that produces human-like text like GPT-3 (Brown et al. 2020), GPT-4 (Open AI), LaMDA and (Google), LLaMa (Meta). The model includes 175 billion parameters and produces high-quality texts. The model generates texts based on a provided text prompt. For instance, if a prompt is the beginning of a story, the model would try to predict the continuation of that story. Several previous applications demonstrated that this model can be meaningfully used for grammar correction, summarizing, answering questions, chatting (Wei et al. 2023), parsing unstructured data, classification, and translation, among other tasks. However, since the model cannot reason, solve mathematical and ethical questions, or pass the Turing test (Floridi 2020), it is regarded as a human-like text generator rather than a general AI in the strict sense.

## Chatbots for Creativity and Design

Several previous studies have utilized human-chatbot interactions to generate creative ideas in various design fields (Shin 2022, Kulcke 2018, Cuadra 2021). For instance, a notable study investigated how humans converse with AI in design tasks (Martelaro 2020). Other studies have explored human-chatbot interactions in spatial design (Kulcke 2018) and ornament design (Cuadra 2021). Additionally, chatbots have been employed to mediate consensus-building conversations (Shin 2022).

Moreover, numerous studies have focused on the development (Ahmed 2020) and evaluation (Tavanapour 2018, Hwang 2021) of chatbots for ideation tasks. Chatbots have also been utilized to facilitate design thinking through the Empathy Map Method (Bittner 2019). An intriguing example is CharacterChat, a chatbot designed to assist writers in creating fictional characters (Schmitt 2021). However, to the best of the authors' knowledge, no studies have specifically examined the use of chatbots in urban design tasks.

The use of diagrams in architectural design is crucial for communicating complex concepts (Do and Gross, 1999). They facilitate collaborative work and efficient idea exchange, especially with the increasing accessibility of visualization applications (Bouchlaghem et al.). Lockard (1973) emphasizes the role of diagrams in exploring design variations and enhancing visual comprehension.

Diagrams as Design Communication

Diagrams in architectural design have been extensively studied, focusing on their role in facilitating communication and understanding of complex concepts. Do & Gross (1999) discuss freehand diagrams in architectural design, highlighting their role in various contexts such as pedagogical books, design studies, designers' introspective accounts, and empirical studies of drawing in design. They argue that diagrams offer a visual means of thinking and communicating in design and suggest the need for computational support for diagrams in design thinking.

Lockard (1973) proposes that the ability to "diagram" an architectural context depends on designers' knowledge of the sun, wind, vegetation, traffic, and surroundings. He argues that diagramming can be used to explore variations of design problems and allows us to "see, comprehend and respond" to more visual information than we can remember from verbal notes.

This idea is further supported by Bouchlaghem et al., who highlights how visualization can assist professionals in architecture and argue that visualization can help designers work collaboratively and communicate ideas more efficiently during conceptual design.

In the context of chatbots, these studies suggest the potential for diagrams to facilitate communication and understanding of design concepts. As chatbots become increasingly sophisticated, incorporating visual elements such as diagrams will augment their ability to communicate complex information and support collaborative design processes. In this research project we will explore the specific ways in which diagrams can be integrated into chatbot interfaces and the potential benefits and challenges of doing so.

# Research objectives & expected significance

The research aims to discover how humans can communicate with AI using text and diagrams conversations. The implications for the use of AI in design are vast and will be explored in the research.

The research objectives and goals are as follows:

**Research goal:** To discover a human-computer communication protocol, based on text and figures, that enhances the exchange of design information in the architectural design process.

**Goal 1:** To establish and formulate metrics aimed ad measuring good communication between humans and between humans and conversational AI.

**Goal 2:** To understand how architects use visual communication modalities, such as diagrams and sketches, to communicate design ideas through identifying and classifying architectural communication artifacts.

**Goal 3:** To evaluate the effectiveness of various design communication text and artifacts experimentally identifying patterns and themes in the communication process using a chat interface.

**Goal 4**: To formulate and experimentally validate an optimal sequence of information exchange based on the findings from the data analysis.

**Goal 5:** To develop and experimentally evaluate a AI chatbot prototype that implements the optimal design communication protocol.

**Goal 6:** To identify potential areas for future research and improvement.

# Detailed description of the proposed research

1. Working Hypothesis: Our previous studies show current conversational protocol between humans and AI in the context of the architectural design process was limited since it is missing graphical design artifacts. In this research project we will augment the design conversations using images, including diagrams, schema, and design artifcats. The research question is what how does an effective and efficient communication protocol between AI and humans look in the context of architectural design?

Secondary research questions are:

1. How to measure an effective design conversation between humans and AI?
2. What are the effective design artifacts for the various stages in the design conversation?
3. Can we model a design conversation and how does it structured?
4. What are the implications of operating a design AI using conversations?

2. Research Design & Methods:

**1.Literature Review:** A comprehensive review of existing architectural design communication artifacts, and human-AI collaboration will be conducted. This will help identify and classify the current state-of-the-art and provide a foundation for the proposed method. In addition, the review will also focus on identifying existing visual architectural communication modalities. This includes understanding how architects currently use diagrams, sketches, and other visual tools to communicate design ideas. The review will also explore how these visual modalities are interpreted and understood by different stakeholders, including other architects, clients, and the general public. This will provide a deeper understanding of the strengths and weaknesses of current visual communication methods in architecture, and help identify areas where a new communication protocol could improve upon existing practices. This will achieve **Goal 1** and **Goal 2**.

2. **Evaluating communication modalities**:

**2.1. Experimental software:** An experimental software system will be developed based on an existing chatbot Wizard of Oz (WoZ) platform. The WoZ method is an experimental interface technology where a human operator, unbeknownst to the user, controls the operation of a system. This method is often used in the early stages of development when a system is not yet fully functional. In this case, the WoZ method will simulate the behavior of an AI system, allowing us to examine the interaction between human designers and the AI system without needing a fully functional prototype. The experiment platform allows recording of the conversations and video of the human participant.

The existing WoZ platform will be extended to include the capability of sending images and allowing both the human user and the operator to annotate and sketch on these images. This will facilitate an interactive and dynamic exchange of design ideas.

**2.2. Experiment:** The Wizard of Oz (WoZ) experimental approach will be employed to evaluate the effectiveness of various design communication artifacts. The experiment will involve architecture students and professionals to ensure a diverse understanding of visual representations.

The experiment will be conducted in a controlled environment and will be video recorded for further analysis according with the Institutional Review Board (IRB) guidelines. The video recording will allow us to capture the nuances of the interaction between the participant and the system, including non-verbal cues and reactions that might not be captured in text-based data.

After the experiment, an in-depth interview will be conducted with each participant. The purpose of the interview is to gain insights into what the participant understood from the interaction with the system. This will provide valuable qualitative data on the effectiveness of the communication protocol.

In addition to the participant's feedback, the operator, who simulates the AI system during the experiment, will also provide their insights. They will document their understanding of the participant's responses and their perception of the interaction. This will provide a dual perspective on the communication process, which can help identify any gaps or misunderstandings in the communication protocol. This comprehensive approach to data collection will ensure that we capture a holistic view of the communication process, which will be invaluable in refining and improving the proposed communication protocol.

**2.3 Data Analysis:** The recorded dialog and video recordings from the WoZ experiment will be thoroughly analyzed to identify effective and ineffective communication. The data will be tagged using a coding scheme developed based on the research objectives. This scheme will include codes for different types of communication (e.g., text, image, video), different types of responses (e.g., understanding, confusion, questions), and different types of interactions (e.g., smooth, interrupted). The coding scheme will be refined iteratively as the data analysis progresses.

The analysis will be conducted in several stages. First, the data will be transcribed and initial codes will be applied. Then, the coded data will be reviewed and refined, with additional codes added as necessary. This process will be repeated until no new codes emerge. Next, the coded data will be analyzed to identify patterns and themes. This will involve comparing and contrasting different codes, looking for relationships between codes, and grouping related codes into themes. The themes will be reviewed and refined, and the data will be re-examined to ensure that the themes accurately represent the data. The outcomes of the data analysis will include a detailed understanding of the communication process, including what works well and what doesn't. This will be used to identify areas for improvement in the communication protocol. The findings from the data analysis will inform the next step of the research, which is the formulation of new hypotheses regarding the optimal sequence of information exchange. The identified themes and patterns will guide the development of these hypotheses, ensuring that they are grounded in the data.

We will also pay close attention to any unexpected findings or anomalies in the data. These could provide valuable insights into the complexities of human-computer interaction and help us refine our hypotheses. In addition, the findings from the data analysis will also be used to refine the WoZ prototype and the coding scheme for the next round of experiments.

This will achieve **Goal 3.**

**3. Formalizing an Augmented Design Dialog:** Once we have a clear understanding of the data, we will use it to formulate a set of hypotheses about the optimal sequence of information exchange. These hypotheses will form the basis of our proposed communication protocol. The protocol will specify the types of information to be exchanged, the order in which they should be exchanged, and the methods of communication (e.g., text, diagrams, etc.) to be used. The goal is to create a protocol that facilitates effective and efficient communication between humans and AI systems in the context of architectural design achieving Goal 4.

**3.1 Validation Experiment (Experiment 2):** The validation experiment will be a crucial step in refining and validating the proposed communication protocol. This experiment will be designed similarly to the initial WoZ experiment (c), but with the implementation of the newly formulated communication protocol.

The purpose of this experiment is to test the effectiveness of the new protocol in comparison to the original method used in the initial WoZ experiment. The same group of participants (architecture students and professionals) will be involved in this experiment to maintain consistency and allow for a direct comparison of results.

The experiment will involve a series of design tasks that the participants will need to complete using the new communication protocol. The tasks will be designed to cover a range of design scenarios to ensure a comprehensive evaluation of the protocol. The performance of the participants in completing these tasks will be recorded and compared to their performance in the initial WoZ experiment. Metrics such as task completion time, the number of communication exchanges needed to complete a task, and the clarity of the design output will be used for comparison.

The feedback from the participants regarding their experience using the new protocol will also be collected through interviews and surveys. This will provide insights into the user satisfaction and perceived ease of use of the new protocol.

The results of this validation experiment will be used to further refine the communication protocol. If the new protocol shows significant improvement over the original method, it will be considered for implementation in the chatbot application. If not, the findings will guide further modifications to the protocol for subsequent testing.

**4. Development of a AI Chatbot Prototype:** Once the optimal design communication protocol is identified, the next step will be to develop a chatbot application that implements this protocol. The chatbot will serve as an AI-powered tool to facilitate efficient and effective design communication between humans and computers achieving **Goal 5**.

**4.1. Prototype creation:** The development process will involve the use of a multi-modal model like GPT-4, which is capable of understanding and generating text, images, and potentially other types of data. This chatbot will be engineered to follow the communication protocol identified in the previous steps of the research. The chatbot will be designed to understand and respond to user inputs in the form of text and images, and generate appropriate responses that adhere to the established communication protocol. It will be capable of interpreting design-related queries, providing relevant information, and assisting in the design process. In addition to GPT-4, we will explore other available models and hybrid approaches. For instance, we might consider using separate text and image generators if they yield better results. The choice of models will be guided by their performance in terms of understanding and generating design-related content, as well as their compatibility with the established communication protocol.

The development of the chatbot will be an iterative process, involving testing, and refinement. The chatbot will initially be tested by the research team, and any issues or shortcomings identified will be addressed in subsequent development cycles. Once the chatbot prototype is developed and refined, it will be ready for evaluation in the human-subject experiment.

**4.2. Human-Subject Experiment:** The performance of the chatbot application will be compared against the results of Experiments 1 and 2. Metrics such as task completion, user satisfaction (measured through surveys), and the quality of the resulting designs (evaluated by a panel of experts) will be used. The data collected from the human-subject experiments will be analyzed to assess the effectiveness of the proposed method. Potential areas for future research and improvement will be identified. This will achieve **Goal 6.**

**Preliminary results**

Our preliminary studies have shown promising results in using chatbots for facilitating design conversations. In a lab experiment, we developed a proof-of-concept chatbot system for design conversations in large-scale urban development projects. The chatbot system was tested and compared to a regular online survey, and the results showed that participants preferred the chatbot experience. The chatbot conversations produced more data than the survey, indicating the potential for chatbots to be effectively used for design discussions in large-scale projects (Dortheimer et al. 2022).

In a field study, we tested a novel crowdsourcing system to automate interactions with a community using chatbots for a 3000-square-meter architecture project in northern Israel. We used a hybrid participatory design workflow that combined traditional face-to-face workshops with one-on-one remote engagement through a GPT-3 powered chatbot. The chatbot effectively fostered introspection and elicited dissenting opinions, while the workshops provided a space for social bonding. The results showed high stakeholder satisfaction and the production of conceptual designs that better reflected stakeholder preferences owing to the improved communication during the design process (Dortheimer et al. 2023).

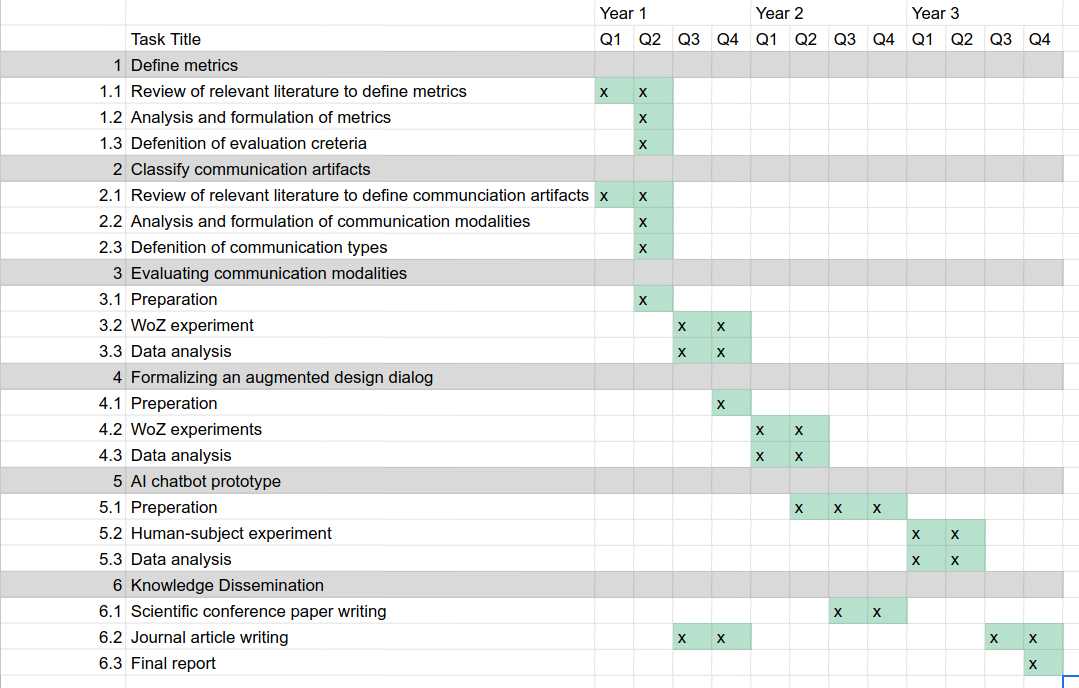
Currently, we test chatbots in large-scale urban planning processes to communicate with stakeholders. While chatbots are a fun and intuitive method of communication, they are limited in communicating complex design information, which is critical for effective participation. Understanding how complex information can be communicated systematically by a computer will significantly improve how humans use AI.

**Existing Facilities**

The project will be conducted at the new Architectural Artificial Intelligence Research Laboratory (AAIRL) at the Ariel University. The laboratory is equipped with all the required research tools, such as computers and recording equipment and has working spaces and personal computers for all the researchers.

# Bibliography

# Time schedule



# Budget

1. Personal:
   1. 25% time commitment of PI.
   2. 1 Postdoc / PhD student
   3. 1 Research assistant
2. Supplies and Materials
   1. Could computing - 10000NIS
3. Services
   1. Website building - 10000NIS
4. Other Expenses
   1. payment for experiment subjects
5. Computers – no need
6. Miscellaneous
7. Equipment
8. Additional Funding - 38K
   1. Frank Petzold TUM / Nikolas Martelaro (Research partners)
   2. Student exchange
   3. Visit in Israel
9. Appendix