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Designing the Built Environment Through Hybrid Intelligence

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Abstract.
There is a lack of an intelligent platform that supports continuous deliberation and captures diverse views and stakeholders' values during the architectural design process in the early stages. Using hybrid intelligence, this study proposes a method that integrates value, and design pattern theories, to support deliberation during the design process. Three steps comprise the method: eliciting value, extracting design patterns, and designing through deliberation with AI agents using natural language processing through hybrid intelligence. The final set of design patterns reflects the participants' values and ideas, facilitating informed consensus and collaboration between stakeholders supported by AI agents. By integrating diverse perspectives into the loop through continuous deliberation, the proposed method incorporates stakeholders' value for extracting design patterns that address primary design goals and challenges such as energy transition in the built environment.

Keywords. Hybrid intelligence, Built environment, Design pattern, Value, Deliberation

1. Introduction

The architectural design process synthesizes diverse disciplines and aspects of human life reflected in the design of the environment [1]. For instance, this process may include factors such as the individual's physical, psychological, and social needs, the design of the space, and the relationship between the user and the environment. The design process plays a key role in translating the needs and wants of intended users into design practice. Architecture should reflect the people who inhabit it and their needs. In the words of [2], it should be designed with people, and the subsequent question is, how do designers transition from designing for people to designing with people? Good design requires a holistic approach considering the environment, culture, and human needs. Indeed, designing the built environment is a multifaceted and complex problem in which various factors must be considered throughout the process. The factors come from various design

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domains, including general design problems like functional and construction problems and addressing design goals like energy transition, circularity, sustainability, etc.

This complexity, therefore, often requires a diverse range of stakeholders involved in the design process. Direct user participation in design and decision-making results in continued insight and knowledge generation [3]. This includes laypeople who will use the final product, technical or functional experts with specialized knowledge of the design, as well as parties with vested interests in its outcome. As two questions proposed by [4]: Can designers align conflicting design objects when they live, work, and act in a public where there is the heterogeneity of perspectives? What are some ways to collaborate around design? Design conflict arises from balancing multiple objectives and vague goals while predicting the unpredictable regarding poorly modeled materials, processes, and people. A successful design requires recognizing and agreeing on significant conflicts early in the process [3]. It is through values that we can understand cultural groups, societies, individuals, and their motivations and attitudes. The values we hold in life are what is meaningful to us in life (for instance, achievement, security, benevolence), each with a different degree of importance [5]. Therefore, it can be challenging to decide which values and goals should guide the design process? And to ensure that the final design reflects the needs and concerns of all relevant stakeholders.

Due to the multidisciplinary nature of the design problems, interactive and participatory designs are ways for parties to exchange ideas to find needs and wants and subsequently define suitable solutions. Dialogue between people presents a means of bringing ideas from different perspectives to solve complex problems. Having a broader vision, therefore, makes solutions more reliable and efficient. Therefore, the design process requires a system of deliberation between experts and users during the design process. As said by [6], that is also important to design processes. To address the challenges mentioned above, it is vital to involve relevant stakeholders in the design process and facilitate a structured dialogue and deliberation process that allows their perspectives to be heard and considered.

The current ways of deliberation in the architectural design process vary widely, but some common approaches include brainstorming sessions, design charrettes, and design reviews, often involving in-person interaction and deliberation. With Building Information Modeling, multidisciplinary CAD data will be captured to support collaborative working environments among stakeholders [7]. Additionally, parametric modeling may be used to facilitate deliberation about design parameters. However, these methods often lack a structured approach to deliberation and a system to capture and incorporate large-scale and multi-actor perspectives from all stakeholders and everyday users. Therefore, architectural design processes lack an integrated and intelligent platform to support continuous deliberation between parties in the initial design phase. This results in some ideas getting lost along the way and some critical factors getting omitted during the design process.

The design process, therefore, requires collecting, storing, and tracking information. This is done by classifying ideas and solutions, analyzing data, evaluating ideas, and, based on the information, establishing feedback and connecting people for further discussion. These features then require the potential use of AI alongside humans in the deliberation process. Moreover, the large number of participants in the participatory design process necessitates implementing deliberation on a digital platform essential. On the other hand, the digital platform enables more participants to be involved in the delib-

eration process. It makes it possible to use AI agents as assistants during the process. Therefore, through the intelligent and interactive deliberation platform, everyday users and experts can collaborate on issues and then find design solutions for each specific design problem with the assistance of AI.

[8] cites Artificial Intelligence (AI) techniques have grown over the past several decades, allowing humans to act intelligently on increasingly complex decisions. Experts, however, have mainly used these tools to date. With hybrid intelligence (HI), humans and machines can work together as mixed teams to achieve shared goals in a synergistic, proactive, and purposeful manner, showing AI's potential to complement rather than replace human intelligence [8]. AI advancements give users powerful new computational tools for solving complex problems, such as monitoring, formulating problems, generating plans, and adapting them. A key issue we face is how to use the power available from new capabilities developing tools to assist human performance, i.e., providing effective decision support tools [9]. Using these tools in conjunction with humans raises new challenges about what needs to be done to couple human intelligence with machine power to optimize overall performance [10]. In the realm of hybrid intelligence, [11] underscores the synergy between AI and human intelligence, which when combined, can lead to superior performance.

By utilizing hybrid intelligence (AI+human), this research supports human deliberation throughout the design process, creating an assistant tool for making informed decisions and reaching informed consensus to achieve solutions and goals for each design problem. AI analyzes what is most commonly discussed via participatory design. It maps users' perspectives connected to the main topics. Through it, people can iteratively be connected to discuss the same interests or conflicts about the issues in more detail. Through deliberation, parties can provide their arguments and vote on each design solution, helping to achieve informed consensus. So, having AI and humans simultaneously through deliberation in the participatory design provides an interactive feedback loop for exchanging ideas. This feedback loop helps ensure that the AI can consider the user perspectives of the stakeholders while providing a platform for people to share their ideas, present their arguments, and work collaboratively towards a viable solution. This deliberation can help build consensus in the design process and foster collaboration between AI and people.

2. Theories

This research consists of three main concepts Deliberation, Design pattern, and Value, each of which will be explained in detail in this section.

2.1. Deliberation

The design process involves many problems from which each specific issue can be extracted. Hence, this research will develop an interactive and intelligent deliberation system where parties can deliberate on design problems. The system will then determine design solutions by storing, synthesizing, and categorizing all data resulting from various dialogues between parties. Thus, the system assists informed decision-making and data-driven design solutions throughout the design process. Then, this tool provides a means for analyzing, evaluating, and providing feedback on the gathered information.

Therefore, developing a deliberation platform in the design process allows parties to consider the design's potential social and cultural impacts. For example, an architect may consider how the building will be used by different groups of people and design the space accordingly. This can help to design and construct buildings that are inclusive and accessible to all members of the community. Furthermore, by engaging in deliberation, parties can ensure that the design of a building is sensitive to the local context and history and helps to enhance the overall character and identity of the community. Accordingly, deliberation is an essential part of the architectural design process and helps to create buildings that are functional, aesthetically pleasing, and have a positive impact on the surrounding community. Access to this digital deliberation platform allows participatory design for designing the built environment.

By studying design activity through interpreting spoken interaction, researchers understand designing as the creative reification process during that interaction [12]. Accordingly, conversations are not just a means to exchange knowledge and information but also a creative activity [13]. Hence, at its core, participatory design involves the direct participation of people in co-designing tools, products, environments, businesses, and social institutions to ensure they are more human-centered [14]. Several methods exist for collecting stakeholder input and feedback, including focus groups, surveys, and interviews. Designers can better comprehend stakeholder values and goals by bringing together diverse perspectives and engaging in the deliberation process. It allows them to incorporate these values into their design process. The challenge, however, is that including more people can be seen as problematic because it suggests that a more diverse design team is needed to create a more successful design output. This could lead to a situation where there are too many cooks in the kitchen, and the design process becomes bogged down by too many conflicting perspectives. So then, there is a need to structure this deliberation process. And the looming question, therefore, is how to structure the deliberation in the design process around the values and goals of users?

2.1.1. Related works

Conversational multiagent systems (CMAS) have been proposed to augment traditional forms of deliberation. Utilizing an agent-based approach, [15] outlines a method for optimizing a deliberation measure quantified through argumentative discussions, making an online democratic deliberation process possible with both human and conversational agents. [16] describes the crowd-scale discussion support system, D-agree, using an automated facilitation agent that extracts discussion structures, analyzes them, and posts facilitation messages. They assessed the social impact of the platform by conducting small-scale and large-scale social experiments in Japan. In a study proposed by [17], an artificial agent is used to moderate online discussions and investigates its influence on the evolution of debates involving human participants. Two experiments were conducted to evaluate the platform's effectiveness in increasing citizen involvement and improving the quality of discussions.

2.2. Value

Incorporating stakeholders' values into the design process is necessary because it demonstrates an understanding of users' needs and perspectives. This provides more meaningful feedback and ensures their concerns are addressed during the design process. Hence,

value is one of the key concepts in this research that help structure the deliberation process. A person's values cannot be driven solely by an empirical description of the external world but must also consider their interests and desires within a particular cultural context [18]. Through iterations on a process that is far more than just the sum of its parts, an artifact (e.g., a system design) emerges that is more than just its parts [18].

One way in which iteratively values can be integrated into the deliberation in the design process is by using value-sensitive design (VSD). Throughout the design process, Value Sensitive Design considers human values in a principled and comprehensive way [19]. As part of VSD, technology design is influenced early in the design process and throughout it [19]. Therefore, VSD is an approach to design that strives to consider the full range of values relevant to the particular design problem and ensures that these values are incorporated into the development process. For instance, designers might consider how the design affects privacy, accessibility, and the well-being of the building's occupants when designing a residential building. Through VSD, designers ensure these values are considered in the design process. This ensures that the final design reflects the needs and concerns of all stakeholders, from building owners and occupants to the surrounding community and environment. The next question is: How do we systematically incorporate users' values into the design process?

2.2.1. Related works

Value Sensitive Algorithm Design, a method introduced by [20], involves a five-step process for designing algorithms in the context of Wikipedia bots. This process starts with identifying and understanding the various stakeholders involved and concludes with evaluating the algorithms' accuracy, acceptance, and impact. Designers interpret stakeholders' viewpoints and make trade-off decisions to ensure the algorithms meet the necessary criteria. Building on this approach, [21] proposes a participatory framework called WeBuildAI, which enables stakeholders to collaboratively design algorithmic policies for their communities. The framework was applied to a matching food donation and transportation service algorithm. Results from this application suggest that participatory algorithm design can enhance values such as fairness, distributive outcomes, and algorithmic awareness while also identifying inconsistencies in human decision-making. In a related study, [22] analyzes conventional decision-making methods and identifies the attributes that influence sustainable design decisions. The authors present a case study comparing the preferences of engineering students, practicing architects, and the public regarding sustainable design features. By taking multiple stakeholder perspectives into account, this study offers valuable insights for value-based sustainable design.

In this research, however, we use value to group design patterns closer to specific values. For instance, in the first project, we aim to filter out users' perspectives and motivations regarding the context of energy transition based on the values that are most important in the built environment and then, based on that, filter out how those motivations and perspectives possibly could shape specific design patterns.

2.3. Design Pattern

[6] notes that it would be necessary to know what has already been done before setting the starting point for the design process. A pattern language is a concept presented by [23] "Town and building will not be able to become alive unless they are made by all the

people in society, and unless these people share a common pattern language," and mentioned that the elements of this language are patterns. According to [23], a system cannot become more true to itself by copying externally imposed criteria of what it should be. Instead, defining a process that reflects the system's nature is possible, providing guidance on how it "ought to be." These processes can be refined to be accessible and understandable by any group of people, ensuring they are explicit and clear enough for widespread use.

Design patterns, initially developed to capture and communicate good architectural design [24], gained interest in academia due to the intellectual climate fostered by Alexander. The intellectual climate developed by Alexander led to an interest in pattern language in academia, focusing mainly on user empowerment, pattern-based design, and community participation, as well as the phenomenological leanings of his theories [25]. Interaction design patterns are a concept similar to Alexander's original patterns written for professionals and non-professionals alike [26]. As noted by [27], developers, business analysts, researchers, and users often need a common understanding of design problems and solutions to achieve successful interface design. Using interaction design patterns improves communication among co-workers from different fields (HCI, IT, business) and users for participatory design [28]. By providing reusable templates adapted to fit the particular issues that designers are addressing, design Patterns could provide designers with the knowledge and experience of creators of successful systems. The Pattern provides a means of communicating between designers of similar products, such as architects and other designers, or between designers reshaping the environment on a much different level, such as furniture designers and interface designers. Knowledge and experience are collected, shared, and amplified in pattern construction iteratively [25].

Alexander's proposal for a design pattern illustrates how it can unravel the puzzle of value hierarchy and value-sensitive design. Design patterns provide a set of proven solutions to common design problems that can help designers address the challenges they encounter during the design process. Hence, in this research, a design pattern is the second key concept that helps to structure the deliberation process. Design patterns are reusable solutions to common design problems that have been used successfully and can be a valuable resource for designers looking for effective ways to solve specific design challenges. As each design pattern can evolve and change over time, deliberation makes it a fruitful avenue for stakeholders to deliberate back and forth ideas about each selected design pattern and make it close to their specific design problem.

2.3.1. Related Work

[29] presents machine learning-based approaches for detecting design patterns, which reduce dimensionality through feature extraction and principal component analysis. To evaluate their performance, a comparative study is conducted using the prepared dataset and comparing it to different machine learning algorithms, including Linear Regression, Polynomial Regression, Support Vector Regression, and Artificial Neural Networks. Cross-validation tests are also conducted to validate their results. A set of modular design patterns for hybrid neuro-symbolic AI systems is proposed by [30] based on a comprehensive review of recent literature. These design patterns include a taxonomically organized vocabulary, over 15 design patterns, and their application in two realistic use cases. The study highlights similarities between systems and extends previous attempts to categorize neuro-symbolic architectures. [31] presents compositional design patterns for hy-

brid AI systems, utilizing statistical machine learning and symbolic knowledge representation techniques. The proposed design patterns serve to systematize literature, clarify the purposes of various techniques, and promote the reuse of software components.

This research envisioned deliberation as a hybrid participatory system. Through participatory design, users input their comments and motivations around their selected design pattern, after which their values will be extracted. AI agents support deliberation by analyzing what values are mostly discussed through deliberation and which are more closely related to design patterns. By mapping values and design patterns, users will be connected to discussing and exchanging ideas to get close to the desired solutions. Based on the context, design pattern, and values each user is most concerned about, AI agents will provide feedback and assist them in reaching their goals and values. By providing deliberation maps using AI, users vote and comment on the final outputs for selecting the final solutions.

To achieve this, this research explores how value and design patterns can be combined to create a new systematic structure for deliberation in the design process. It also seeks to consider the potential benefits and limitations of this approach. During the design process, designers and stakeholders can integrate deliberation to ensure that the values and interests of all relevant stakeholders are considered and prioritized. This will contribute that the final design reflects their concerns and needs. However, there are some potential drawbacks to this approach as well. For example, getting all stakeholders to agree on a common set of values can be time-consuming and difficult. Additionally, this approach may not be suitable for all design projects.

3. Research Objective

This research will develop AI techniques to develop a deliberative assistant system for designing the built environment. So, the main research question is: How can AI interactively support continuous deliberation through a common pattern language among multiple actors for designing the built environment to align with stakeholders' values? It aims to provide an interactive dialogue system through a deliberation platform to make new design patterns and solutions for each specific issue and to utilize and expand existing design patterns to solve new design problems. This research also aims to develop different agents as a design assistant tool that helps users throughout the deliberation process. AI agents, as an assistant, analyze needs and solutions based on the existing data to explore the aggregated data and compare them with new data for giving feedback to users by visualizing the data. For example, through hybrid intelligence, we will categorize solutions and essential keywords, find possible conflict issues, connect ideas and solutions and connect expertise, merge designed patterns, and make feedback by generating similar concepts. This leads to four sub-questions:

1. How can a digital deliberation platform be designed and implemented to support effective participatory design processes? 2. How can a hybrid intelligence approach extract design patterns from various datasets relevant to building and energy transition? 3. How does using a digital deliberation platform impact the outcomes of participatory design processes? 4. How can the use of existent design patterns be integrated with public participation and stakeholder engagement in the design of the built environment?

4. Approach

This research contains three main concepts: Value, Design Pattern, and Deliberation. In this research, values and design patterns will be integrated to develop a structure for deliberation, as can be seen in Figure 1 below where it starts with applying NLP techniques to a large survey corpus to extract design patterns considering how topics and themes, and values are distributed, then categorizing design patterns based on their values, giving initial input where users can add their ideas and revising and adjusting design patterns based on the new problems and challenges that need to be addressed. The method includes three steps:

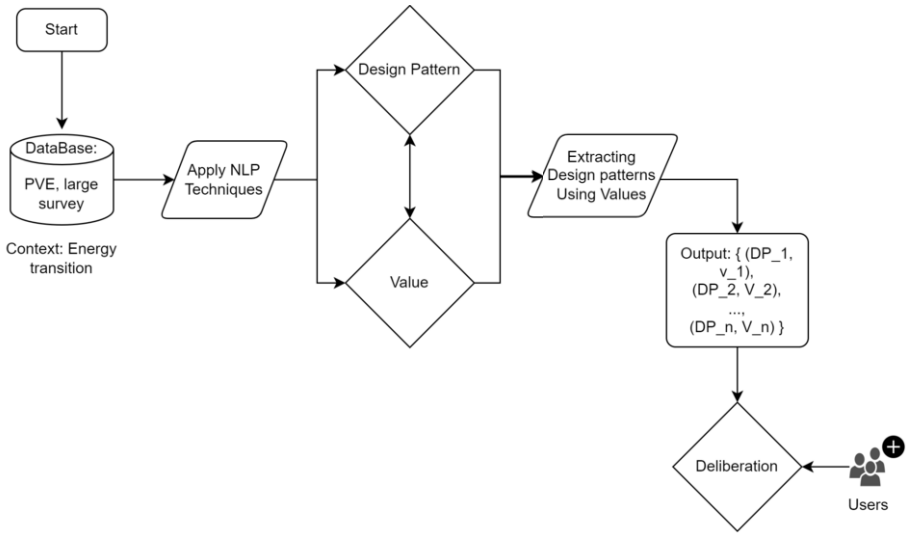

Figure 1. The flowchart illustrates how all three concepts (Design pattern, Value, Deliberation) are related

Step 1: Value Elicitation with NLP Techniques:

First, considering values, this research aims to find answers to how and to what extent AI can assist humans in value elicitation. Considering large survey databases like Participatory Value Evaluation (PVE) where citizens can participate at a large scale using an online tool. It puts citizens in the seat of decision-making. They can spend the public budget on a selected set of projects [32]. Using NLP techniques as AI tools, this research analyzes users' motivations in the participatory evaluation system (PVE) to extract and connect human values to their motivations. For doing so, the PVE database will be analyzed using NLP to monitor how motivations are distributed around values and grouped with similar topics. For this purpose, in this step, we will investigate how a hybrid intelligence approach using Active Learning can fine-tune BERTopic models for context-specific topic extraction. The method improves topic modeling performance by incorporating human-annotated data on uncertain examples. Applied to a Participatory Value Evaluation dataset, the research aims to enhance topic coherence, domain knowledge alignment, and context-specific value identification.

Step 2: Design Pattern Extraction using Hybrid Intelligence:

As a second step, the method uses hybrid intelligence techniques to extract design patterns around the identified values. Monitoring motivations connected to values for

specific topics provide insight into the possible design patterns that can be found and extracted around each topic-value. We will use the information extracted from the previous step (Motivation, Topic keywords, Values) to generate a design pattern by feeding them into a large language model (LLM). Then, through a series of experiments, we will examine how derived design patterns can be refined and aligned with human preferences. To do so, participants will evaluate outputs by annotating and giving feedback on design patterns. We will use this feedback to improve the model and to create a final design pattern that accurately reflects user preferences. Finally, the design pattern will be used as an initial step for deliberation.

Step 3: Designing through Deliberation:

Design patterns and values play an initial input in this step, which implements an interactive exchange of ideas where users can select, comment, revise DP, and value. In this step, The experts will engage in interactive deliberation to revise and change each design pattern based on their expertise and insights. The AI system will facilitate communication between experts and support recommending relevant design patterns and suggesting revisions. Based on this, users can be connected to other users with the same or conflicting ideas. By engaging users in interactive deliberation, users can integrate their ideas into the design process and achieve their goals through back-and-forth ideas for reaching optimal design solutions. Then, users' ideas are tracked and analyzed using AI and NLP techniques to create a deliberation map for each design problem. The deliberation map shows how users' ideas are related and connected. The AI system assists in creating the deliberation map by suggesting recommendations for users to connect with others with similar or conflicting ideas. This step provides AI agents to assist users in the design process. The agents provide relevant information and recommendations based on the user's input. They also help users navigate the design process and give feedback on the effectiveness of their ideas. In the final step, participants select the set of design patterns as a pattern language they want to use for the design process. The selected pattern language is the result of the deliberation process, and it reflects the values and ideas of the participants. Figure 2 illustrates an example of how users deliberate using the hybrid intelligence method and how it forms a deliberation map.

5. Research Challenges

Several challenges are expected to be encountered during the research project, including data collection and compiling quantitative and qualitative data relevant to the design patterns. Data collection has been challenging since cleaning data suitable for an AI model takes time and precision. First, this research will extract design patterns based on the available database relevant to energy transition and the building sector. Extracting these patterns requires gathering information from different sources, such as corpus, and PVE, making it challenging to use the same methods for extracting desired outputs.

Second, after extracting the available data types relevant to the building sector and energy transition, the second challenge would be classifying issues in order and organizing the patterns from the very largest to small and most detailed ideas. [23] pointed out that design patterns in the design process start with considering the town and region and then working through the neighborhood and cluster of the building, room, and then detail of the construction. So, the second challenge is to make the extracted database in this order considering two keywords, building and energy transition.

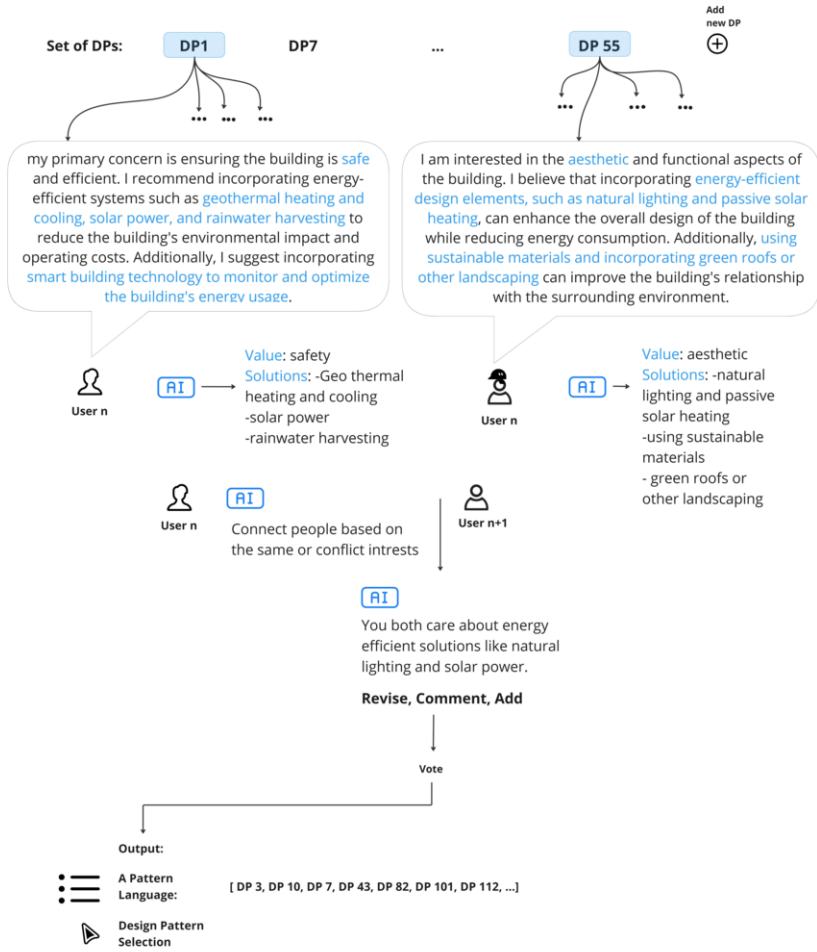

Figure 2. An example of a deliberation map

Third, Data quality and bias, One of the main challenges of using NLP techniques in value elicitation is the quality and bias of the data used. The data used in the PVE system may not represent the entire population or may be biased toward certain groups or values. This can lead to inaccurate or incomplete results, which can affect the overall success of the method.

6. Discussion and future work

The research methods propose developing an interactive framework that integrates values and design patterns to facilitate a participatory design process through deliberation to bring broader perspectives for solving the complex challenges we face in designing the built environment. We aim to improve the interaction among multiple stakeholders and

laypeople who are involved in the design process to create a democratic design process whose values will be aligned with the design goals. This can be done by encouraging open dialogue and collaboration among all stakeholders, allowing everyone to have a voice in decision-making. By doing this, the design team can ensure that the design goals are grounded in the stakeholders' values, leading to a more equitable and successful design process. This can be achieved through hybrid intelligence, which combines human-centered design with data-driven decision-making. By leveraging both approaches, the design team can create a holistic view of the problem and develop creative solutions that meet the needs of all stakeholders.

Our methods can be used to support the architectural design process where multiple stakeholders need to exchange ideas for addressing design challenges and goals. It also has the potential to be extended to contribute to other design sectors, such as urban planning and product design, where participatory design can be implemented to support the design of sustainable and resilient communities. This could involve adapting the method to these sectors' specific needs and characteristics and exploring new tools and techniques to facilitate the participatory design process.

7. Evaluation

In future experiments, the proposed research method can be tested in real-world projects to evaluate its effectiveness in facilitating the building sector's participatory design process for the energy transition. Such evaluations could refine and improve the method and its tools and techniques. For instance, a pilot project will be established in which the method is applied to the participatory design process of a specific building project. This will involve stakeholders representing different disciplines and interests. For this purpose, a pilot will be conducted after extracting possible DPs from a large survey corpus. This pilot will evaluate how and to what extent the extracted DPs align with human preferences. In the structure of a DP [23], As stated in each solution, it gives the basic relationships necessary to solve a problem, but in an abstract and general manner- so that you can find the solution to your problems on your own, by adapting it to your own preferences. Based on this, two criteria will be defined: relevancy, which elaborates on how a DP well represents the information extracted from the large corpus, and clarity, how a problem-solution is fitted and how well a DP is reusable. Therefore, we need human intelligence to evaluate how a DP can be revised to meet human preferences. Two statistical analyses will be used; first, quantitative analysis will compare the revised DP to the extracted version to see to what extent involving human intelligence can refine a DP by comparing their scores. Second, using qualitative analysis, we will categorize and count the suggested changes for each criterion to identify common themes and trends in the feedback. It helps to investigate whether certain types of suggested changes were associated with larger improvements in the scores or if specific aspects of the DPs were particularly challenging for participants to improve. Participants review and give feedback on the proposed DPs through a feedback loop system. Then, comparing the revised DP to the first version gives insight into how the method can be adapted for generating new DPs out of the participatory evaluation corpus.

Conflict of Interest Statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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