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Leveraging Large Language Models in Capturing Architects' Social Design Intentions in Buildings – A Case Study

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1. Introduction

The social dimension of the overall sustainable development concept is characterized as subjective and situation-dependent compared to the relatively straightforward economic and environmental dimensions [1]. In the built environment, social sustainability is represented in building certification systems (e.g., DGNB) by aspects of a functional nature, such as thermal, acoustic, and visual comfort, accessibility, indoor air quality, and integration of art [2]. Capturing such important qualities is often at the risk of losing intentions due to the continuous and frequent updates of digital building models among stakeholders, especially in large-scale building projects.

In this work, we investigate the capability of Large Language Models (LLMs) in digitalizing and integrating architects' ***Social Design Intentions (SDIs)*** into digital building models. That is, when a design choice (e.g., installing art) is intended to elicit a social intention (e.g., curiosity). If documented concisely in the building model, this eliminates ambiguity and facilitates stakeholder communication. The following research question addresses this challenge:

RQ: How can LLMs be utilized to capture and digitalize architects' SDIs in digital building models, and to what extent is the generated output syntactically and semantically accurate? This research question reflects the novelty of our approach, as currently, there are no existing socially oriented decision-support software tools in the domain of the built environment that particularly target capturing SDIs and how they can be integrated into digital building models.

2. Methods

This work builds upon our case-study-based framework ***"ProFormalize"*** [3], which aims to develop a software tool that enables architects to capture SDIs in digital building models. In ProFormalize, we developed the ***"Product-Goal Causality Model"***, a domain-specific data model to formalize, represent, and reason about SDIs in the built environment. The term "causality" refers to the ***cause-and-effect*** relationship between building elements (i.e., the product level) and the evoked social intention (i.e., the goal level), through the domain-level, as shown in Figure 1.

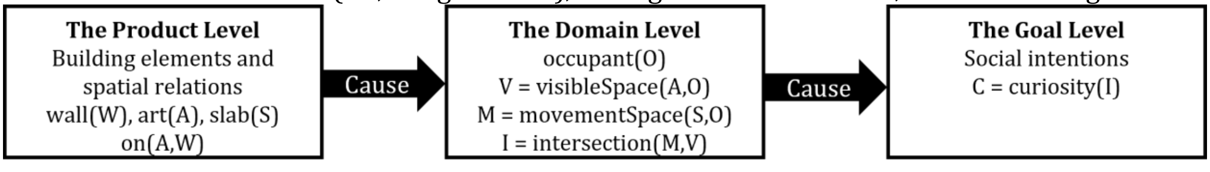

Figure 1. Illustrative diagram of the product-goal causality model. Social intention "curiosity" is elicited by installing art(A) on wall(W). The intersection(I) between the visible space(V) of the art and the movement space(M) of the slab, is the region where social intention is elicited among (O).

This model breaks down the SDI into three levels: ***the product level***, ***the goal level***, and ***the domain level*** (containing spatial regions created by building elements).

In the software implementation part of ProFormalize, we developed **"ProSpect"**, a plugin integrated into Autodesk Revit, guiding the user through a wizard of 4 steps to create an SDI. The created SDI can be exported as a text file structured based on a pre-defined specification. The exported text file can then be processed in our SDI analyzer tool, with which users can query SDIs and check for syntax and logical errors in the SDI specification. The overall process of ProFormalize has been conducted following a "***co-creation"*** approach in which actual potential users of the tool (i.e., architects) have been involved in the development process. Regarding ProSpect, interviewed architects pointed out that the wizard involves a lot of clicks to create the SDI, affecting its overall functionality. Hence, we investigate the potential role of LLMs in generating the text file specification of the SDI based solely on its natural language description. Figure 2 shows the process from navigation of a building model to the analysis of the LLM output.

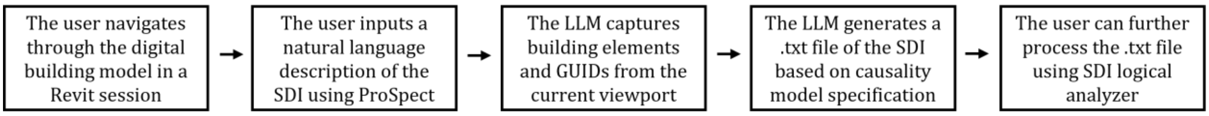

Figure 2. The overall process of user interaction with ProSpect and ProFormalize Analyzer

In the initial stage of this work, we conducted a walk-through, semi-structured interview with an expert architect in building renovation projects and recorded 80 SDIs. We were guided by the architect to explore several buildings where SDIs have been implemented. This work focused on one of those buildings in which 12 SDIs were recorded. An interview guide was used by the interviewers only to elaborate on certain aspects, avoiding any bias that might result from asking the architect to explain a specific instance. The SDIs were recorded as they were mentioned, transcribed, organized, and finally formalized according to our model.

The second stage of this work was divided into 2 parts. In the first part, which is called ***"the untrained session"***, we explored the formalization capability of ChatGPT of selected SDIs (SDI39-SDI50), without any training on already-formalized SDIs. In the second part, which is called ***"the trained session"***, we trained ChatGPT using 2 external formalized SDIs and prompted it to formalize the same 12 SDIs accordingly. Both sessions used the (GPT-4o) model with a clear memory, assuring no bias in the sessions and emphasizing a user-centred co-creation approach.

3. Results

The average similarity with the original specification was 70.5% in the untrained session compared to 79.8% in the trained session (Figure 3). For all SDIs, the trained session had a higher similarity with the original specification compared to the untrained session. The LLM-generated output showed high accuracy in defining building elements and assigning their corresponding GUIDs. However, the number of specified spatial regions and relations was significantly lower compared to the original specification (Figure 4). Table 1 shows the similarity between the generated specification and the original specification, where the highlighted spatial region (e.g., movementSpace), spatial relation (e.g., intersection), and the domain-level element in which the social intentions are elicited, were the weakest captured compared to the original

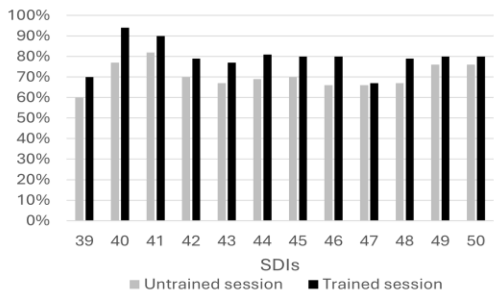

Figure 3. Similarity to original specification

text. This is because LLMs process text sequentially, lack spatial reasoning capability, and do not accurately construct spatial configurations of relations and regions without visual or geometric data. Hence, further training on domain-specific SDI terms might improve the LLM's performance.

```
SOCIAL_DESIGN_INTENTION SDI39
DESCRIPTION Colored acoustic panels wrapping the corner and sticking out
            from the wall, building users will feel curiosity.
ELEMENT AP Product BuildingElement AcousticPanel 0MhmdHhPn1gfTOSV6p8SLd
ELEMENT W Product BuildingElement Wall 0RcWmeMI93EPbrLGYO8AD$
ELEMENT S Product BuildingElement Slab 2FUJ3oalz07gH3F0tjaNXw
RELATION Product On AP W
ELEMENT O Domain Occupant []
ELEMENT V Domain VisibleSpace AP O
ELEMENT M Domain MovementSpace S O
ELEMENT I Domain Intersection M V
ELEMENT C Goal SocialIntention Curiosity I
```

```
SOCIAL_DESIGN_INTENTION SDI39
DESCRIPTION Colored acoustic panels along a corner in a hallway.
            The panels are wrapping the corner and sticking slightly
            out from the wall. The building users will feel curiosity
            about what is around the corner.
ELEMENT A Product BuildingElement AcousticPanel 0MhmdHhPn1gfTOSV6p8SLd
ELEMENT W Product BuildingElement Wall 0RcWmeMI93EPbrLGYO8AD$
ELEMENT S Product BuildingElement Slab 2FUJ3oalz07gH3F0tjaNXw
RELATION Product On A W
ELEMENT O Domain Occupant
ELEMENT V Domain VisibleSpace A O
ELEMENT C Goal SocialIntention Curiosity V
```

Figure 4. Example case: Original specification (left) vs LLM-generated specification (right) of SDI.

Table 1. Relative capturing degree of some SDI elements vs the original specification

SDIs	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	
BuildingElement	✓✓	✓✓	××	✓✓	✓✓	✓✓	✓✓	××	✓✓	✓✓	✓✓	✓✓	
GUID	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	**P**
Spatial Relation	×✓	✓✓	×✓	✓✓	✓✓	✓✓	✓✓	×✓	××	××	××	××	
Occupant	×✓	×✓	×✓	×✓	×✓	×✓	×✓	×✓	×✓	×✓	×✓	×✓	
Spatial Region	××	××	××	×✓	××	××	××	×✓	✓✓	××	××	××	**D**
Spatial Relation	××	××	××	××	××	××	××	××	✓✓	××	××	××	
Social Intention	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	**G**
Domain Element	××	××	××	××	××	××	××	××	✓✓	××	××	××	

Untrained session ■ Trained session ☐ Weakest areas **P**: Product level **D**: Domain level **G**: Goal level

4. Conclusion

We investigated the potential of LLMs in digitalizing architects' SDIs in buildings. We aimed to provide architects with a tool that integrates such aspects into digital building models, without affecting their reasoning about their designs. Therefore, we concluded that LLMs, with efficient and accurate training, can capture this logic and transform it from natural language description to our model's specification. As future work, we will continue our co-creation process, inviting external architects to assess our tool and the capability of the trained LLM to capture SDIs.

5. Acknowledgements

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References

[1] Almahmoud E, Doloi HK. Identifying the key factors in construction projects that affect neighbourhood social sustainability. Facilities. 2020 Sep 10;38(11/12):765-82.
[2] Stender M, Walter A. The role of social sustainability in building assessment. Building research & information. 2019 Jul 4;47(5):598-610.
[3] Zayed YN, Kristoffersen AE, Lohm G, Kamari A, Schultz C. The Anatomy of an Architect's Argument: Formally Capturing Socially-Oriented Design Intentions in the Built Environment. In Proceedings of the 2024 European Conference on Computing in Construction, 2024 Jul 14.