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Abstract. In an era where digital transformation shapes most facets of business and society, haptic Design Thinking workshops emerge as a valuable driver to foster co-creation and human-centric design among interacting stakeholders. Still, a need persists to capture workshop results in a digital and machine-processable manner. Scene2Model exemplifies these capabilities by enabling an automated transformation of physical scenes into conceptual modeling-based representations. To support this process, novel features are introduced within this work that leverage generative Artificial Intelligence (AI), such as Large Language Model-based object description and attribute generation, along with comprehensive scene summaries. Moreover, the application of the Scene2Model tool in collective intelligence environments is supported by automated postings of results, thus exemplifying the potential to enhance collaborative evaluation and feedback. This approach emphasizes the potential of combining haptic Design Thinking with advanced AI technologies, marking a significant advancement in the refinement of Digital Twins for Haptic Design Thinking.

Keywords: Scene2Model, Digital Twins for Haptic Design Thinking, Co-Creation, FAIRWork, CoDEMO 5.0

1 Introduction

Alongside the ongoing digitalization, which redefines today's business landscape as well as the social interactions related to it, the Digital Twin concept has gained popularity across various fields. Traditionally, the concept has been applied in physical settings related to manufacturing and production. Nowadays, the Digital Twin paradigm shifts towards more immersive interpretations that also consider non-tangible aspects as potential application fields, thus requiring the exploration of novel and user-friendly methodologies. In this context, *Digital Twins for Haptic Design Thinking* have been proposed as an intuitive approach to extend the traditional view of Digital Twins.

The aim of this contribution is to showcase an innovative prototype that supports this novel notion, namely Scene2Model[1]. This tool was first introduced in the scientific

[1] `https://www.omilab.org/activities/scene2model/`

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literature in 2018, enabling the automated "*transformation of tangible Design Thinking artefacts into diagrammatic models with the simultaneous semantic enrichment of the objects*"(Miron et al. 2018, p.1). Scene2Model thus addresses the challenge of capturing the physical results of Design Thinking workshops in a digital form to ease the documentation and sharing with relevant stakeholders beyond the initial participants (Karagiannis 2024*b*). Since then, Scene2Model has been applied in research, teaching, and industry projects, which has provided valuable inputs for iterative improvements. The most recent features resulting from these improvements are discussed in this contribution.

For this purpose, the theoretical background regarding Design Thinking, related concepts, and the foundations of the Scene2Model tool are introduced in Section 2. Subsequently, the prototypical application of Scene2Model is showcased in Section 3, covering new functionalities and current applications within selected research projects. Finally, key takeaways of this contribution are summarized in Section 4.

2 Theoretical Background

The foundational concepts of Design Thinking are introduced in the theoretical background, emphasizing the importance of co-creation and collective intelligence. Following this, the Scene2Model tool is presented as a facilitator for digital Design Thinking.

2.1 Design Thinking, Co-Creation, and Collective Intelligence

The trend of adopting Design Thinking across multiple domains has resulted in diverse methodologies, as shown in Karagiannis (2024*b*). Central to each of these approaches is a focus on human-centric design (Brown 2008) that is particularly valuable in multidisciplinary settings often associated with digital transformation, as it brings together stakeholders from distinct backgrounds to yield collaboration and co-creation of involved entities. Moreover, there is a trend towards interactive workshops utilizing tangible objects based on pen and paper, independent of the employed methodology (Schelle et al. 2015). These materials aid in building a shared understanding among participants, enabling them to convey their insights through physical means. Fundamental aspects supporting this process are collaboration and co-creation, concepts that have been present in human society for millenniums (Bhalla 2011*b*). Nowadays, often associated with involving consumers in the design of products or services, the understanding has shifted towards the general inclusion of all stakeholders relevant to a given design process (Bhalla 2011*a*, Ind & Coates 2013). These concepts are relevant within the context of Design Thinking workshops as they leverage the integration of varied viewpoints originating from the interacting stakeholders. Addressing this dynamic, the term *Collective Intelligence* has been established to describe the enhanced capabilities that can emerge when diverse groups of individuals synergize their unique knowledge, skills, and perspectives (Leimeister 2010). This phenomenon is exemplified in Design Thinking workshops, where participants from varied domains collaborate actively. Hence, Design Thinking methodologies and corresponding workshops fulfill the foundational principles of collective intelligence by leveraging diverse ideas across disciplines based on collaboration and co-creation to develop creative as well as innovative solutions.

2.2 Digital Design Thinking using Scene2Model

It has been emphasized in the previous section that Design Thinking methodologies rely on physical workshops and tangible materials to foster collaboration, co-creation, and collective intelligence. The Scene2Model tool addresses the challenge of capturing the results from such workshops by providing an automated mechanism to transform them into digital, conceptual models, currently specific for the storyboard methodology (van der Lelie 2006) using SAP Scenes[2]. In this context, Scene2Model provides an environment in which a camera stream is harnessed to detect paper figures of a specific scene via an attached QR-Code and then translate these into corresponding modeling objects. Afterward, the transformed objects can be semantically enriched within the environment through further information, additional attributes, or adjusted representations (Muck 2024). Detailed explanations of the Scene2Model tool, its implementation based on the ADOxx metamodeling platform (Karagiannis 2024*a*), and recent applications within an educational setting of the OMiLAB innovation environment have been presented in related works (e.g., Miron et al. (2019), Muck & Palkovits-Rauter (2022), Voelz et al. (2023*b*,*a*), Völz & Vaidian (2024)). Therefore, these aspects are not discussed hereafter as it would exceed the scope of this contribution focused on newly developed features.

3 From Digital Design Thinking Towards Digital Twins for Haptic Design Thinking: The Evolution of the Scene2Model Tool

The Scene2Model tool has been applied in various domains and projects after it was first introduced in the scientific literature. Since then, it has been iteratively evolving towards a novel notion labeled *Digital Twins for Haptic Design Thinking* in recent works (Voelz et al. 2023*a*, Karagiannis 2024*b*, Völz & Vaidian 2024). This notion extends the common understanding of the Digital Twin concept, which is traditionally applied in the context of the manufacturing domain. To also account for non-tangible elements being virtually represented by a Digital Twin, wider definitions have been proposed, for example, Digital Twins of a system (Kirchhof et al. 2020). Building on this notion of the Digital Twin concept, three foundational components can be identified: (i) Models representing the system under study (ii) that are built upon data traces from the system (iii) while offering services aimed at deriving meaningful implications for the system.

Considering these components, early Scene2Model versions already met the first two. The following section presents how recently developed functionalities contribute to the third component (i.e., deriving meaningful implications). The development of these functionalities is fundamentally driven by the Agile Modeling Method Engineering (AMME) lifecycle (Karagiannis 2015), which defines a structured process for the realization of modeling methods. Moreover, AMME emphasizes the importance of iteratively refining modeling methods, like Scene2Model, to address changing requirements and integrate new technologies. In line with such iterative refinements, Large Language Models (LLMs) are harnessed to extend the functionalities of Scene2Model for a more context-aware modeling environment, as showcased subsequently.

[2] `https://apphaus.sap.com/resource/scenes`

3.1 Prototypical Functionalities of Digital Twins for Haptic Design Thinking

Subsequently, it is assumed that Design Thinking workshop results (cf. Section 2.1) are transformed into digital models using the Scene2Model tool (cf. Section 2.2). Based on these assumptions, three prototypical functionalities are showcased below, which aim to derive meaningful implications for a system under study from the inherent model value.

LLM-based Object Description and Attribute Generation The first functionality makes use of novel advancements regarding generative Artificial Intelligence (AI) and, more specifically, LLMs with the goal of leveraging their expectations for semantics-driven systems engineering (Buchmann et al. 2024). After the translation of haptic paper figures into digital modeling objects, semantic enrichment can be performed by prompting for further suggestions describing attributes of the individual objects within the scene. Still, this process requires relevant domain knowledge and potentially further coordination among workshop participants to reach an agreement regarding generated descriptions. Considering these elaborations, a prototypical feature was added to Scene2Model during the last iteration of the AMME lifecycle (Karagiannis 2015) to generate object descriptions and attributes for recognized objects automatically.

The following Figure 1 exemplifies how this functionality is utilized for a scene of hospitality services in Japan[3], namely for the actor "Receptionist". A corresponding prompt is sent to an LLM via HTTP request to receive a relevant description, which is then saved under the attribute "Description" of the respective object.

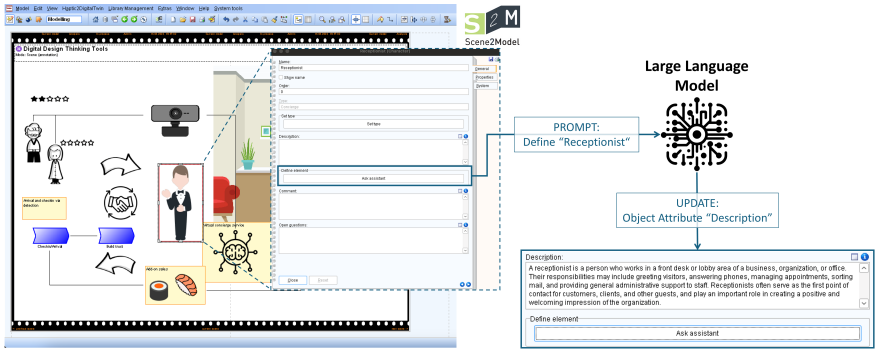

Figure 1. LLM-based generation of an attribute description for the modeling object "Receptionist"

LLM-based Scene Summary The final result of the storyboard methodology is a collection of scenes that sequentially represent a coherent storyboard. With the goal of providing textual descriptions of each scene for documentation purposes or for visually impaired people, an LLM-based scene summary is provided as a new feature within the most recent Scene2Model version. The summary is created through an engineered prompt that takes every transformed modeling element as input to create a summarizing description for selected scenes. Such summaries serve as additional documentation

[3] This scene will serve as an example throughout the chapter on the prototypical functionalities.

and can be used for scene validation purposes or advanced sharing functionalities to synergize a collective intelligence that goes beyond the initial workshop participants.

For the scene depicted in Figure 1, the triggering of this functionality results in the LLM-based generation of the summary displayed in Figure 2 by sending a corresponding prompt via HTTP request that considers each object represented in the scene.

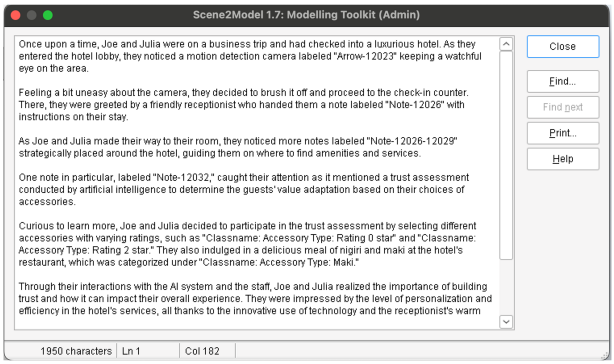

Figure 2. LLM-based generation of a scene summary for the scene depicted in Figure 1

Scene Evaluation in Collective Intelligence Environments The third functionality aims to break the limitations of distributed teams by facilitating the transfer of ideas within dedicated platforms. Both created models and the LLM-generated descriptions of scenes can be automatically posted within relevant working platforms, such as Microsoft Teams (cf. Figure 3). In this way, not only the opinions of workshop participants but also all relevant stakeholders that are included in a specific design process can be considered. Further, the stakeholders' input can be processed (e.g., using sentiment analysis (Yue et al. 2019)) to provide an overview of opinions to workshop participants.

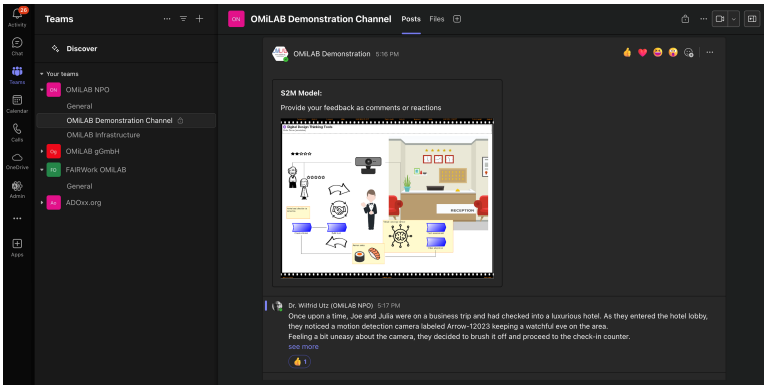

Figure 3. Automated posting of a scene and its summary (cf. Figure 1, 2) within Microsoft Teams

3.2 Current Application Contexts of Scene2Model

In the following, two selected research projects in which Scene2Model is utilized are presented to provide an overview of the current application contexts.

FAIRWork is a research project aiming to improve flexibility and worker participation in complex decision-making processes by developing an AI-supported and configurable decision-support system (DSS). Further details about this project can be found on the project webpage[4] and in (Woitsch et al. 2023). Through the Scene2Model tool, decision problems and the related human requirements for complex decision processes can be effectively captured within the FAIRWork project, enabling a comprehensive understanding of the underlying system and scenarios. The captured knowledge is then further utilized in the formalization of decisions that serve as input for a flexible and model-based configuration of the system, thereby allowing non-experts to understand the decisions better and ease the adaptation to changing requirements.

CoDEMO 5.0 is a research project that aims to support decision-makers of organizations from different sectors in transitioning toward sustainable and human-centric strategies in a co-creative manner. Further details on the project and the role of *Digital Twins for Haptic Design Thinking* can be found on the corresponding project webpage[5] and in (Voelz et al. 2024). By employing the Scene2Model tool, CoDEMO can effectively capture the externalized knowledge from diverse stakeholders, thereby fostering a multi-dimensional understanding of complex systems. This approach supports the project's objectives of advancing sustainable, resilient, and human-centric principles in Organizations 5.0 and also exemplifies the innovative approaches to enhance collaborative decision-making and value co-creation within the European innovation ecosystem.

4 Conclusion

This contribution showcases how prototypical functionalities of the Scene2Model tool can be utilized to open up new opportunities for collaborative and co-creative environments, exemplified through the application within selected research projects. Through our exploration, we highlighted Scene2Model's role in transforming the tangible outputs of haptic Design Thinking workshops into digital representations, enhancing collaborative creativity and decision-making processes. In projects like FAIRWork and CoDEMO 5.0, Scene2Model facilitates a seamless transition from physical objects, serving as data traces, to digital representations of the respective system under study. Subsequently, these objects can be further enriched with added semantics and interoperability, offering a more comprehensive and dynamic approach. Moreover, newly developed features of Scene2Model enable the generation of object descriptions, attributes, and scene summaries, as well as the sharing in dedicated environments to foster evaluation through principles of collective intelligence. The goal of the functionalities is to derive meaningful implications for the original system, thus fulfilling the requirements to be considered *Digital Twins for Haptic Design Thinking*. The insights from corresponding applications illustrate the growing possibilities that lie at the intersection of traditional Design Thinking and advanced technologies, forming the basis for future developments and applications that can leverage these integrative approaches for innovative solutions.

[4] `https://fairwork-project.eu/`
[5] `https://codemo-project.eu/`

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