A Recognition Service for Haptic Modelling in Scene2Model

Neural Networks for Design Thinking

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Abstract

Design thinking has gained popularity in recent years as a toolbox to support the development of innovative business models, product offerings and services. Applying a user-centric paradigm during the co-creation phase of stakeholders with various backgrounds, where ideas are created, prototyped, and iteratively evaluated. A challenge observed in such settings relates to how knowledge about novel ideas can be communicated and developed in collaborative settings, specifically from the perspective of processing artefacts realised. We will introduce the Scene2Model tool, developed in the OMiLAB@University of Vienna as a way to tackle this challenge. Scene2Model enables the digitalisation of design thinking artefacts, developed using haptic elements as conceptual models. The tool supports a dynamic metamodel representation and builds on training results to a) recognise the haptic elements as model concepts, b) elevate the Scene2Model metamodel continuously with domain-specific vocabulary and c) align these concepts with external definitions on type level. The digital models in Scene2Model become therefore digital representations that can be annotated and refined, queried or transformed as model value capabilities. This paper provides a demonstration of this idea.

Keywords

Digital design thinking, Conceptual prototyping, Conceptual modelling, Storyboarding, Digitalisation of design artefacts, Image recognition, Concept recognition

1. Introduction

Design Thinking - as the use of designers' problem-solving techniques applied to innovation processes - has gained popularity in a variety of industry sectors.Held in closed workshops, it paves the way for early exploration and validation of design alternatives regarding innovative services, new product (and features), processes and disruptive business models by means of

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collaborative agile ideation, prototyping and testing techniques [1]. One possible result of Design Thinking workshops is a low-fidelity prototype, used to gather early (user) feedback.

A prerequisite to establish location and time-independent interaction during design relates to the digitalisation of design artefacts within the iterative innovation process. Such a digitalisation needs to go beyond digital drawing or photos of physical design results. Instead, semantically rich representation enable interaction on a granular level. For this purpose, conceptual models are suggested as a technique to represent the knowledge about innovative scenarios and expose it to the community. Conceptual models require a vocabulary that is domain-specific and well-understood by the participants. SAP Scenes [2] are a set of predefined graphical elements, the combination of which allows to sketch storyboards during the empathise phase of design thinking and about products or services that are created during the ideate phase.

2. State of the Art:
Digital Design Thinking using Conceptual Models

Scene2Model [3, 4, 5] is an environment that allows to digitise physical storyboards by using QR codes to identify the conceptual model elements for each physical object. The Scene2Model environment has been successfully demonstrated in various research and industrial initiatives [6] as part of the OMiLAB Digital Ecosystem introduced in [7] and [8]. This ecosystem builds on the notion of conceptual models that go beyond communication and establish model value through processing, whereas the educational and training aspect as discussed in [9] is an important aspect, specifically in the field of information systems design.

As already outlined in [10], domain-orientation is considered a critical aspect as it "reduces the large conceptual distance between problem-domain semantics and", generalizing Fischers statement, the intended representation of the system-under-study. Co-evolution is realized as the designer have agreed upon a common vocabulary that is adequate for the problem space and have access to relevant knowledge of various stakeholders.

The drawback of this approach is that it requires manual effort to attach QR codes to each physical object and that only the QR codes are detected and not the attached figures themselves. To overcome this drawback we developed machine learning approach for image recognition. The knowledge about the visualisation of the haptic elements, in our case paper figures, is trained and represented as a convolutional neural network to support the later recognition of elements via a video stream, observing the design thinking workshop.

Additionally, the approach applies the Agile Modelling Method Engineering (AMME) approach [11], to adapt the Scene2Model domain concepts to the needs of the concepts in the workshop. The focus hereby is on the design and formalise phase, when new concepts and their graphical notation are added. While in [12] an approach is presented that allows to extend the SAP Scenes, in this work we deal with the linkage of the physical world and the digital world.

3. Method and Concept: Recognition of Haptic Elements

The scope of this paper is the extended Scene2Model environment, graphically shown in Figure 1 above. Participants of a workshop utilise haptic objects, typically paper figures to describe

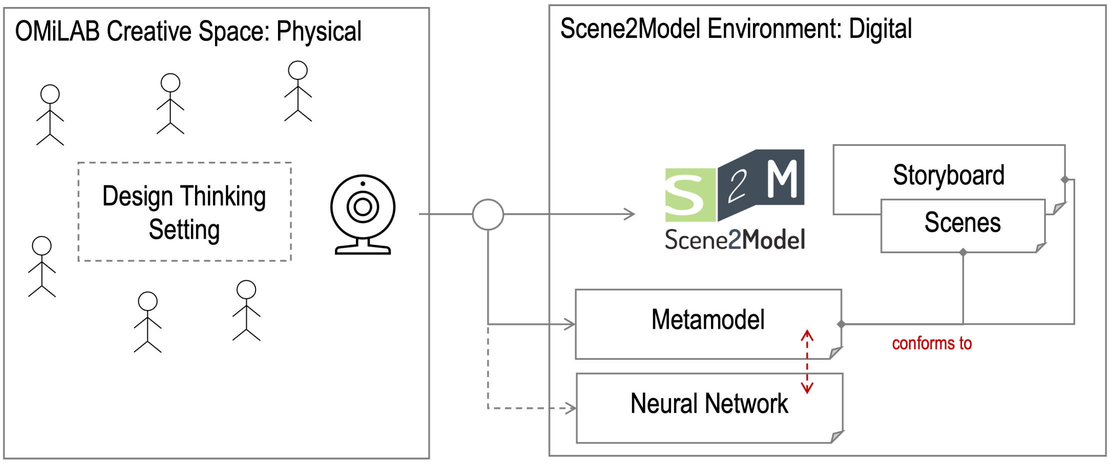

Figure 1: Digital Design Thinking using Scene2Model

and discuss scenarios. Scene2Model supports these workshops by a) constantly capturing the design space as a video stream and b) translating the physical scene developed into a model representation. Various approaches have been evaluated to perform this task: the initial prototype operates on QR tag recognition as introduced above. Each haptic element is extended by a tag that can be detected. The position information is then retrieved and the ID within the QR code is used to query an ontological representation of the concept. Utilising the capabilities of ADOxx [13], the information is imported in the tool as individual modelling objects that form the scene discussed. The challenge in this setting is the synchronisation of the metamodel used in Scene2Model for the realisation of processing functionality with the ontological representation and QR codes available. Extension or domain-specific adaptation implies a (re-)engineering of these artefacts.

The objective of the research presented in this paper is to combine image recognition with conceptual modelling and knowledge representation. Adding a new graphical system typically consists of two steps: First a drawing of the object is made that is adequate for the specific domain. Second, the knowledge base of conceptual elements is extended to enable a digitalisation within the tool. The second step is now supported by neural networks: the image retrieved is trained beforehand and dynamically extends the metamodel. Therefore, adaptation becomes feasible and it is not required to manually engineer the knowledge base. The recognition server is responsible to provide the interface between the image providing service (e.g. camera, video stream, mobile phone) and the Scene2Model modelling tool. This interface is established via the OLIVE micro-service framework [14].

Therefore we distinguish between a training phase which is used to prepare the domain-specific workshop vocabulary and provide the network to the recognition server. Based on the training outcomes, the metamodel is extended and the graphical elements are not only available as haptic figures but also understood by the tool.

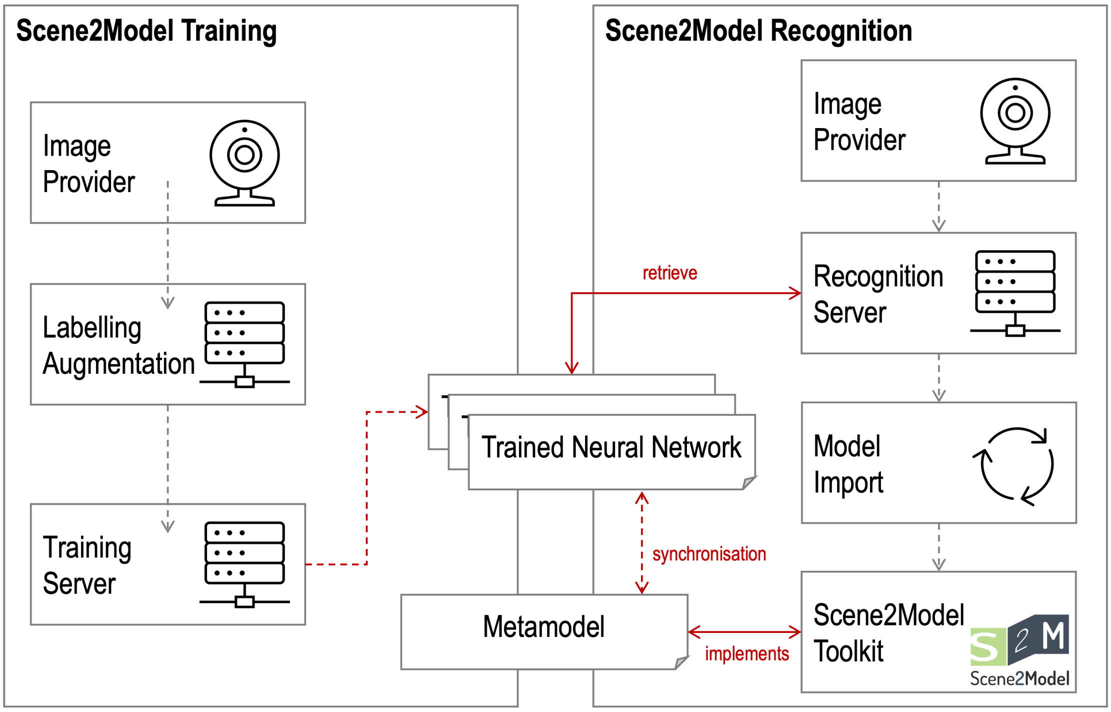

Figure 2: Scene2Model Component Architecture

3.1. Scene2Model Recognition Architecture

This section introduces the object recognition architecture for conceptual models, including input to the training and executing the detection. For our implementation we use the YOLOv4-tiny [15], which is based on YOLOv4 [16] and supports the requirement of real-time object detection and a fast training. Both are relevant for the Scene2Model environment as results should be available directly in the workshop situation. The initial definition used was the YOLOv4-tiny definition available online at [17].

3.2. Preparation Phase: Training and Metamodelling

As the preparatory activity to capture the domain (conceptual analytics), the visual elements are identified, the semantics of identified elements are elevated in a machine supported manner using open accessible dictionaries and the convolutional neural network is trained for recognition. The objective of this phase is to establish a domain-specific metamodel for Scene2Model dynamically as the vocabulary to be applied. This has an impact on the Scene2Model tool as it is dynamically adapted to support the semantics of the domain and trained concepts.

Technical, this requires the creation of a labeled dataset. Example pictures are prepared (photos and labelling) and further data augmentation is applied [18] resulting in a moderate dataset that includes artificially blurred, cut-out or distorted versions of the image. The training itself is performed using darknet [19].

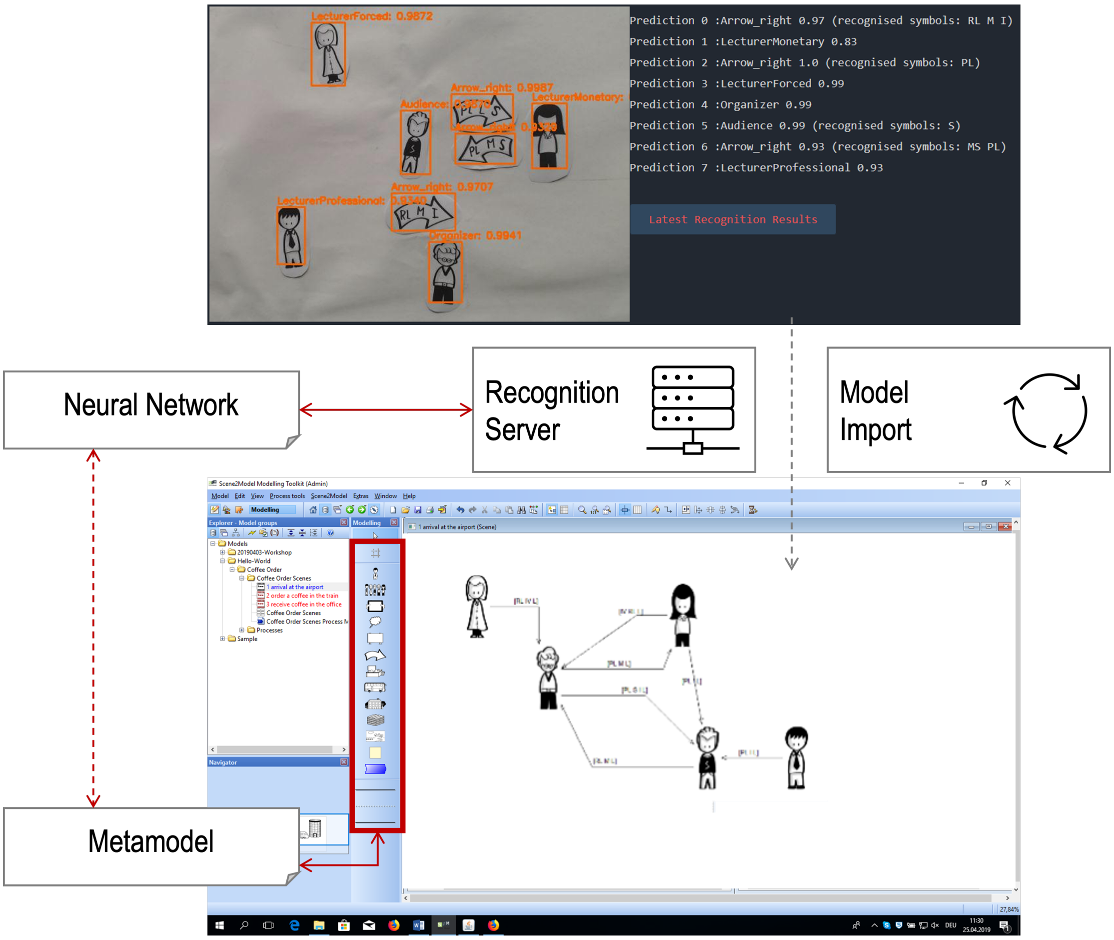

Figure 3: Scene2Model: Recognition Implementation

As an outcome, the trained network is provided on one hand to the recognition server and on the other hand acts as input for the knowledge base represented by the metamodel in Scene2Model. The Scene2Model tool dynamically adapts to these changes and includes the new elements as a domain-specific version.

3.3. Recognition Phase: Design Thinking Workshop Support

After the network is trained it is used to detect objects in the image stream from the workshop. The recognition server implemented in Python provides the necessary interfaces to perform this recognition and manages the trained networks. As an interchange format a JSON representation is returned from the recognition that is embedded in the Scene2Model tool utilising the OLIVE micro-service environment [14]. The stream is transformed into the conceptual model, and since the training network is aligned with the Scene2Model metamodel model processing capabilities can be applied.

Managing multiple networks is considered an opportunity to include pre-trained information directly, without the need to extend manually and run through the training phase.

The synchronisation of the knowledge base adapts the known concepts in Scene2Model. The knowledge base, represented as a knowledge graph, is parsed and mapped toward the abstract metamodel definition. Mechanisms in ADOxx enable that the metamodel can be update during runtime. The modelling panel therefore represents the trained concepts structurally. Syntactically properties are dynamically retrieved through openly available sources such as DBPedia.

4. Conclusion and Next Steps

This iteration of the Scene2Model prototype demonstrates how the metamodel is dynamically updated based on training of neural networks for object detection. The approach presented builds on pre-existing approaches in object detection and related techniques for training of neural networks and applies it to design thinking and conceptual modelling.

Further work and next steps relate to the evaluation of the approach, specifically how domain-specific libraries can support various settings in workshops and capture domain-specific aspects dynamically.

These steps are currently worked on in the context of the FAIRWork EU project [20] where Scene2Model is utilised in the requirements engineering phase.

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