Process Modeling Within Augmented Reality

The Bidirectional Interplay of Two Worlds

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Abstract. The collaboration during the modeling process is uncomfortable and characterized by various limitations. Faced with the successful transfer of first process modeling languages to the augmented world, non-transparent processes can be visualized in a more comprehensive way. With the aim to rise comfortability, speed, accuracy and manifoldness of real world process augmentations, a framework for the bidirectional interplay of the common process modeling world and the augmented world has been designed as morphologic box. Its demonstration proves the working of drawn AR integrations. Identified dimensions were derived from (1) a designed knowledge construction axiom, (2) a designed meta-model, (3) designed use cases and (4) designed directional interplay modes. Through a workshop-based survey, the so far best AR modeling configuration is identified, which can serve for benchmarks and implementations.

Keywords: Augmented reality · Process modeling
Simulation process building
Generalized knowledge constructin axiom · Meta-model · Use cases
Morphologic box · Industry 4.0 · CPS · CPPS · Internet of things

1 Introduction

Faced with a first process modeling approach augmenting common process models [3], the augmentation process is still uncomfortable and limited to various issues, such as the following examples show: First, a modeling is based on a rather demonstrative than complete set of modeling objects. It is not clear, which kinds of modeling objects are required to realize the full potential of an AR modeling. Second, it is not clear what the full potential of an AR modeling is connected to. First attempts show potentials in regard to non-transparent processes, a spacial positioning following a Cartesian definition, and identify attractive modeling contexts, such as knowledge-intensive processes, highly communicative behaviors and Industrie 4.0 scenarios [3]. But these are assumingly not the only potentials. Third, an AR modeling is based on a prototype character of workflows. It is not clear, which kinds of modeling activities shall be realized as before, and which

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kind of modeling activities can be enabled by the use of AR hardware. Fourth, it is not clear by which kinds of modeling operations AR modeling activities can be carried out and are carried out best. Each concrete AR hardware provides individual characteristics and a standard in AR hardware is not available, yet.

Especially the interplay of the more or less paper based 2D world of a process modeling and the 3D AR modeling world is attractive to overcome previously mentioned issues and progress the AR modeling.

In this contribution, an *AR modeling* is referred to more than the simple enrichment of 2D modeling shapes and the positioning within the real world. It considers the process of the model construction, its visualization as static models and dynamic simulations, and the optimization of created process models, which can be realized by all: It can be realized with help of ordinary computer systems and modeling tools in the common 2D modeling world, it can be realized with help of AR hardware and modeling tools to be created in the 3D AR modeling world, or it can be realized with help of an integration of both.

Hence, the following research will focus on modeling with help of AR technology with the intention to answer the following research question: "How can processes be modeled within the augmented world?" This paper intends not to draw an all-embracing description of concrete, technical realizations of those novel process modeling techniques. It intends to set a first step to an integration of both modeling worlds. Hence, sub research questions are:

1. "How can an AR modeling be specified systematically?"
2. "How can process modeling be realized best in both worlds?"

Based on the assumption that each model creator wearing AR glasses or using other AR devices has a proper reality, the challenge lays in the synchronization of realities during a modeling cooperation process including numerous model creators. The original scientific contribution of this research therefore is an attempt to synchronize individual realities of an AR modeling by the creation of an *AR modeling framework* and the identification of a best configuration.

The research approach is intended to be design-oriented as Peffers proposes [13], such that the paper is structured as follows: The second section presents a foundation and underlying concepts, the third section derives objectives and presents a methodology for the specification of a bidirectional interplay of the common 2D modeling world and the 3D AR modeling world. Those are separated from the design of required artefacts, which will be presented in the fourth section. Their demonstration presented in the fifth section shows the application of designed artefacts. This is evaluated in the sixth section. Then, the final section concludes the paper.

2 Theoretical Foundation and Underlying Concepts

The first sub section presents approaches for model definitions, so that an interpretation for an AR modeling can be selected. Then, meta-model approaches are collected, so that a foundation for the meta-model design is available. Finally, basic control concepts are provided, which will be used for an AR modeling.

2.1 Model Definition Approaches

Some authors see the reason for the diversity of the term "model" in the history of its definition because definitions are based on separate thinking traditions [15, p. 2]. In accordance to Thomas, model definitions can be categorized by the following categories [20, p. 8]:

First, *Stachowiak's common model theory*, who defined a model to be the realization on an at least quintary predicate relation, which refers to the model x of the original y for the model user k within the period t and the intention z [17, p. 118].

Second, *axiomatic model definitions*, that are based on mathematical definitions using the field of mathematical logic, set theory, propositional calculus, predicate logic, etc. [19].

Third, *mapping-oriented model definitions*, which assume models to be mappings of the reality [7, p. 321]. Hence, the performance of the model creator is restricted to the selection of attributes being mapped to the model.

Fourth, *construction-oriented model definitions*. Those assume the reality not to be existent: Since each model creator perceives the reality from its own perception, it constructs its own reality [21, p. 9]. Hence, the creation of models (mentally or explicated) is highly creative and interpreted as construction process [20, p. 25].

Faced with the assumption of each model creator wearing proper AR glasses to construct its own reality, a construction-oriented model definition is attractive. This kind of definition will be the foundation for the *knowledge construction axiom* designed in Sect. 4.1.

2.2 Meta-model Foundation

In principle, meta-models of modeling languages provide taxonomies, that classify modeling objects following certain criteria [5, p. 66]. In literature, meta-models can be found, which provide perspective-oriented modeling taxonomies or approach-oriented taxonomies.

Perspective-oriented taxonomies list modeling items in regard to a certain modeling perspective. The following perspectives can be identified: *Functional*, *activity-oriented*, *behavioral*, *organizational*, *informational information flow-oriented*, *resource-oriented*, *knowledge and knowledge - flow - oriented* and *business process context* perspective ([9, p. 1533], [18, p. 3310]).

Approach-oriented taxonomies list modeling items in regard to one of the following approaches: *Activity-oriented approaches*, *role-oriented approaches*, *object-oriented approaches* and *speech-act-oriented approaches* ([8], [5, p. 67]).

In this contribution, a perspective-oriented meta-model will be provided in Sect. 4.2, since visualizations of AR modeling objects can focus only on relevant items of one of many perspectives. Hence, for the augmentation irrelevant objects can be suppressed perspective-wise.

2.3 Control Concepts

This sub section presents a collection of basic control concepts, which will serve for the operationalization of AR operations. Although a variety of concrete AR operations can be derived from given concepts, this contribution focuses on a first attempt and limits itself to one AR operation per control concept.

Buttons as graphical software elements serve as shortcut for functionality provided by software. Further, *guided processes* present graphical elements in an inherent manner, such that a sequence of simple activations of buttons, augmented representations, menu views, etc. collects information required by programs. Wherever possible, *workflows* realize mechanisms in the background. An activation can be realized easily by a *cursor* and a *touch pad activation*. Alternatively, a movement of the arms can be tracked by a camera, such that a *computer vision* recognizes movements specified in advance. A selection can be realized by the focus of eyes on an object (eye focus analysis). An activation can then be detected by an in advance specified eye blinking pattern (image or video analysis) [14]. Being recorded by a microphone, voice-based instructions can be recognized in regard to a specific context efficiently (speech recognition) [10] and serve as control command. Even EEG electricity can be used for a thought detection, such that instructions are tagged automatically similar to Koelstra et al. [6].

3 Objectives and Methodology

Following the DSRM approach [13], this section identifies objectives independent from a design. Then, a methodology is presented that satisfies methodological objectives. These are separated from the design and its demonstration, so that artefacts can be created and then, the fulfill of requirements can be evaluated. Following a methodological foundation, designed artefacts give evidence in a demonstration in regard to their functioning.

3.1 Objectives

Aiming to prepare a bidirectional interplay of the 2D modeling world and the 3D augmentation world, this section presents a set of requirements that has to be considered in the realization of artefacts. Requirements are presented category-wise. The first category refers to modeling languages in general, the so called meta-level of modeling languages. The second category is connected to the usage context of modeling languages, the here called scenario creation. The third category refers to AR hardware characteristics and serves for the selection of appropriate AR hardware. A fourth category focuses on methodological requirements.

In regard with a meta-level of modeling languages, the following objectives have been identified:

- The modeling shall support the creation of various process domains (knowledge-intensive, business, production processes, etc.) including state-of-the-art systems.

- The modeling shall support the creation of process simulations.
- The modeling shall support the use of several modeling languages.

With respect to the scenario creation, the following objectives have been identified:

- The modeling shall consider typical modeling scenarios.
- The modeling shall consider both modeling worlds (2D modeling and 3D AR).
- The modeling shall consider each model creator to have an own reality.
- The modeling shall synchronize model creator specific realities.

Focusing on the hardware selection (AR glasses or tablets), the following criteria were relevant additionally to AR technique inherent requirements such as the positioning within an area, performance issues, etc.:

- AR techniques shall provide a touch pad.
- AR techniques shall provide a microphone.
- AR techniques shall support the connection with further systems (eye tracking systems for eye focus analyses, online computer vision systems, EEG electricity detection systems for thought detection, etc.).
- AR techniques shall have WLAN access.
- AR techniques shall have Internet access.
- AR techniques shall support common basic operations.

Each identified objective of those three domains has been relevant for the design of the bidirectional interplay of the 2D modeling world and 3D augmentation world and serves as input for the following sections. Following a certain methodology, the following requirements have been identified for the methodologically backed-up creation of an AR modeling framework:

- Artefacts shall characterize an AR modeling by quantified parameters.
- Artefacts shall present an overview of possible solutions.
- Artefacts shall be expandable easily.
- Artefacts shall be constructed iteratively.
- Artefacts shall support a validation by empirical research.
- Artefacts shall support a validation by implementation and use in projects.

Based on the latter six requirements, a methodological foundation focuses on a morphological analysis.

3.2 Morphological Analysis

Following Zwicky, the *morphological analysis* is suited to explore all the possible solutions to a multi-dimensional, non-quantified complex problem for various domains, such as for instance in anatomy, geology, botany and biology [23, p. 34]. It is widely accepted and the history of morphological methods is summarized by Ritchey [16].

Being part of the general morphological analysis, the morphologic box, the so called *Zwicky box*, is constructed in five iterative steps [22]: First, *dimensions* of the problem are properly defined, which refer to relevant issues. Second, a spectrum of values, the so called *parameters*, are defined for each issue. Then, by setting the parameters against each other in an n-dimensional matrix, the morphologic box is created. Here, each cell of the n-dimensional box represents one parameter and marks a particular state or condition of the problem complex. Hence, the selection of one parameter of every dimension, the so called *configuration*, represents a solution of the problem complex. A fourth step scrutinizes and evaluates possible solutions in regard to the intended purpose. In a fifth step, the optimal solution is practically applied. If necessary, insights from the application are considered in previous steps.

4 Design of the Bidirectional Interplay

The design of a bidirectional interplay of the 2D modeling world and the 3D AR modeling world is based on the following parts. First, a *knowledge construction axiom* is presented. This is considered within a second sub section in the design of a *meta-model*. The third sub section presents *use cases* required for an AR modeling. Then, the interplay of both modeling worlds is characterized by the design of *directional interplay modes*. All of them can be considered as sub artefacts designed for the creation of the main artefact called *framework for the bidirectional interplay*. Their creation sequence, artefact relation and theoretical foundation is visualized in Fig. 1, so that the scientific contribution indicated by an asterisk (*) and theoretical foundation can be recognized.

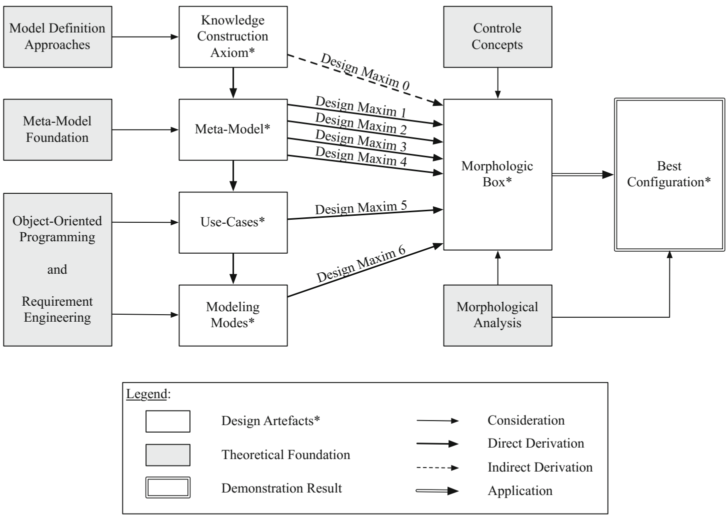

Fig. 1. Artefact creation.

In this figure, it becomes clear that the morphologic box can be considered as main artefact. *Design maxims* are derived from each sub artefact and serve for the construction of a morphologic box representing the *framework for the bidirectional interplay* of the 2D process modeling world and the 3D AR modeling world. Following the proceeding of a morphological analysis, its application serves as demonstration in accordance to Peffers et al. [13] and identifies a best configuration.

4.1 Knowledge Construction Axiom

Following a construction-oriented model definition, the reality is created by the perception of a subject (see Sect. 2.1). Since the production and company-wide processes in general are based on concepts constructed by subjects, any material transportation, conversation, work realization, etc. is based on the application of knowledge.

Knowledge-intensive processes can be operationalized on base of the SECI model [11] using *conversions*. The Knowledge Modeling and Description Language (KMDL) is an example for a modeling language using conversions [2]. Here, four kinds of conversions (*internalization*, *externalization*, *combination*, *socialization*) conceptualize the knowledge creation. Although the SECI model was originally meant as concept for knowledge creation, it can be generalized for value creation processes, which is denominated as *knowledge construction axiom* from here on. A generalization can be applied as follows:

Intentional material and data manipulations incl. their transfers are interpreted as combinations, where the corresponding objects are enriched to explicit knowledge in interpreting them within the context of the current activity. This refers to North's requirement of the enrichment by a *meaning* and *contextual embedding* [12, p. 41]. The enrichment can be carried out either by CPS or computer systems that have been enabled through information objects, such as computer programs, transportation orders, etc. Alternatively, they have been enabled by humans or CPS through knowledge objects, such as for example the intended production, transportation by themselves.

Non-intentional conversions, such as real-world processes (e.g. weather) and physical laws (e.g. gravity) are neglected based on the following interpretation: Even the interpretation of real world processes is created with intention and only by the subjective perception of the individual. Here, the observation of physical phenomenas (as-is values are collected) and its comparisons with to-be values, which are based on the beliefs and expectations of the individual, leads to the adjustment of the individual's beliefs and their making explicit (e.g. in form of physical laws). Hence, their use within process models is always associated with the use of information objects.

Enabled through this generalization, the knowledge construction axiom will be considered in the design of a meta-model for modeling languages and implicitly in the design of the morphologic box (Design Maxim 0).

4.2 Meta-model

Following the idea to identify AR-suited modeling activities, which can be beneficial for many modeling language approaches, the following presents a meta-model for modeling languages.

Since the meta-model integrates a great number of foundational concepts and abstracts over a range of modeling languages, a common understanding of modeling is addressed and a community-wide acceptance supported. The meta-model further tries to provide a state-of-the-art modeling concepts, that considers state-of-the-art concepts, such as Industry 4.0 components. The meta-model can be seen in Fig. 2.

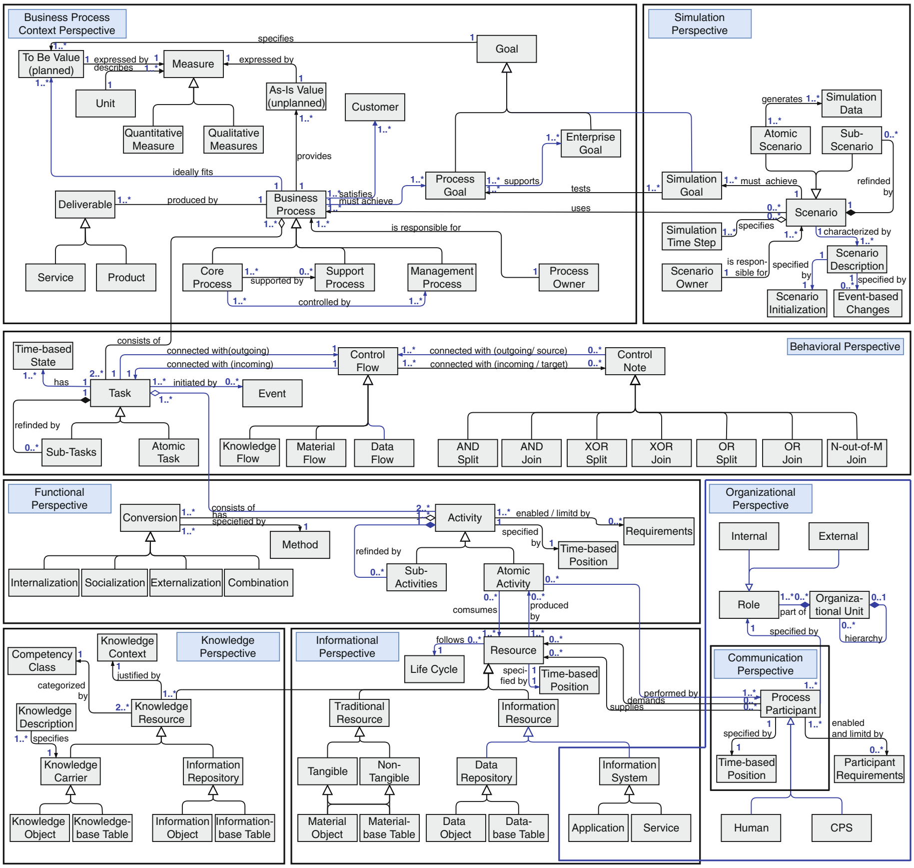

Fig. 2. Meta-model of a bidirectional AR modeling.

In this figure, one can find gray objects representing modeling objects. In accordance with Booch, objects are related by the following kinds of relations:

using relations are represented by arrows, *aggregations* and *compositions* by blanc and black diamonds, *inheritances* are represented by blanc triangles [1]. Required cardinalities can be found next to corresponding relations. Perspectives identified in Sect. 2.2 are boxed. Their title is highlighted in blue. Based on the model of List and Korherr [9], the meta-model presented here complements a knowledge perspective, a simulation perspective and a communication perspective, which were identified in literature. While additional objects and relations are drawn, others were only updated. Required cardinalities complement the meta-model too, which simplifies the implementation. In interpreting Fig. 2, the following independent design maxims can be derived:

Design Maxim 1. Considering the great amount of modeling objects, one can identify only some modeling objects being connected with "time-based positions". The focus of the modeling within the AR world shall lie on those activities.

Design Maxim 2. One can see that hierarchies of elements are established within complex task structures, complex activity structures and complex scenario structures. Hence, their organization is best realized within the 2D modeling world.

Design Maxim 3. The organization of knowledge objects, information objects, material objects, data objects and organizational units including humans and CPS can result in great hierarchies. Therefore, all those modeling objects are well suited for the organization within the 2D world, but can easily be completed by the positioning within the real world via AR techniques.

Design Maxim 4. Since the simulation is carried out in the background but leads to attractive visualizations of time and position based modeling objects, only the positioning of time-based objects is attractive for a scenario creation within the 3D AR world. Further, the simulation controlling is essential in both worlds.

Summing up, the meta-model serves for the derivation of a collection of design maxims. Those will be the foundation for the design of a bidirectional AR modeling.

4.3 Use Cases

In order to identify relevant dimensions for the bidirectional AR modeling, required operations were identified by the construction of a use case diagram. The use case diagram can be seen in Fig. 3 and considers perspectives identified in Sect. 4.2.

With focus on the model creator or the so called *actor*, who would like to create a model using an arbitrary modeling language, use cases within the 2D modeling world are visualized on its left and use cases within the 3D AR world are collected on its right side. While the 2D world is accessed by a common 2D modeling tool, which is here *Modelangelo* on a desktop or laptop [2], the 3D AR world is accessed by a common 3D AR modeling tool, which is here the

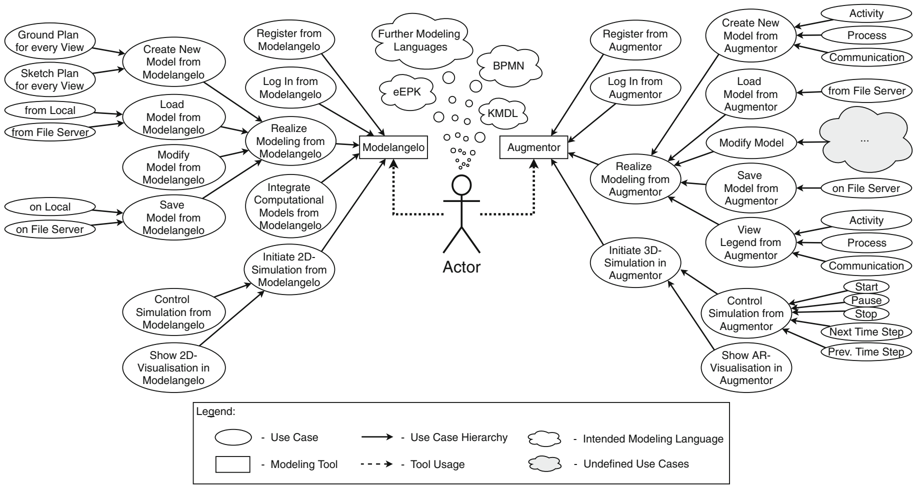

Fig. 3. Common use cases for a bidirectional AR modeling.

Augmentor on a tablet or AR glasses [3]. Since both are built to provide various modeling languages, the programs are suited for the generalization of common use cases for a bidirectional AR modeling.

The use case diagram of Fig. 3 shows basic operations, such as register, load and save activities, which can be found in both modeling worlds. They support working on a *local platform* and the use of *cloud services*. The model creation within the 2D modeling world considers the positioning of modeling objects within the AR world using a *ground plan* and *sketch plan* as well as the extension of modeling objects with 3D models following concepts of Grum and Gronau [3]. The focus of this contribution shall lie on the construction of models within the AR world, since a modification in the 2D modeling world is widely spread. In Fig. 3, this is represented by a gray cloud showing dots and is specified in a later section. The following design maxim can be derived:

Design Maxim 5. Use cases identified in the use case diagram presented here are interpreted as basic operations and will be required in both modeling worlds.

Summing up, the use case diagram serves for the derivation of a design maxim in regard to operations required for an AR modeling in both worlds. Those will be the foundation for the design of a bidirectional AR modeling integrating the 2D world and the 3D AR world.

4.4 Directional Interplay Modes

Dependent on the intended modeling situation, four kinds of *AR modeling modes* can be identified: First, the *no-interplay-mode*, which allows a modeling only within the 2D modeling world or within the 3D AR modeling world. Second, a *one-person-mode*, that realizes a modeling in both modeling worlds for a single person. Third, a *collaboration-mode*, that realizes a modeling in both modeling worlds, while only one person is modeling and others give feedback based on visualizations. Fourth, a *muliple-device-mode*. Here, various model creators are modeling cooperatively using different kinds of modeling devices. The modeling modes can be seen in Fig. 4.

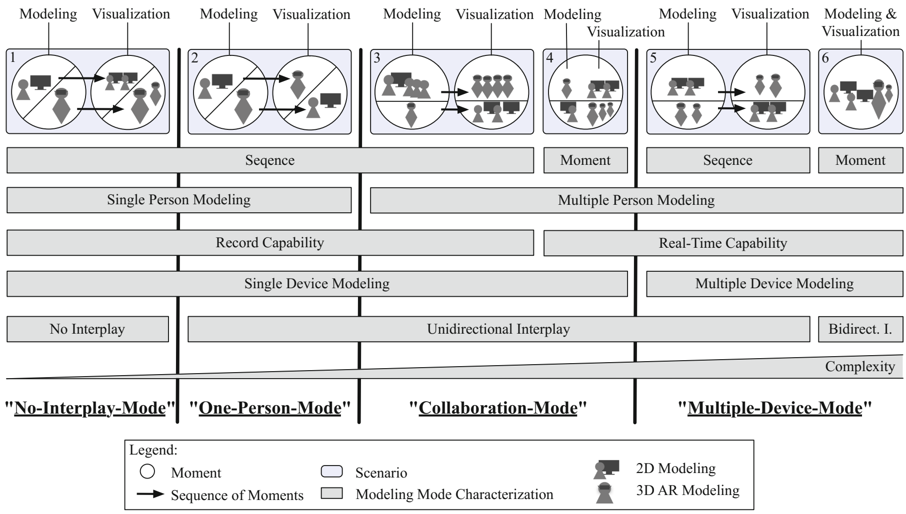

Fig. 4. Common modeling modes for an AR modeling.

The modeling modes are connected to one of six *modeling scenarios* (visualized on the very top). The first scenario refers to two moments. In a first moment, the modeling is carried out either in the common 2D modeling world using desktops and laptops, or in the 3D AR modeling world using AR devices. Then, in a second moment, constructed models are visualized within the same modeling world. The second scenario refers to the model construction in one modeling world and the visualization in the consecutive moment within the other modeling world. The third scenario refers to the model construction in one modeling world and the visualization for many individuals within the other modeling world. The fourth scenario integrates the first and the second moment of the third scenario in one moment. The fifth scenario enables several model creators to work on one model within the same modeling world and to visualize this model for many individuals in a second moment within the other modeling world. The sixth scenario integrates the first and the second moment of the fifth scenario in one moment and connects both modeling worlds bidirectionally.

The realization of each scenario demands different implementation requirements, which are visualized by gray rectangles within the figure. The following independent design maxim can be derived:

Design Maxim 6. Implementation requirements refer to both modeling worlds and characterize an AR modeling.

Since implementation requirements characterize an AR modeling, they will serve as dimensions for the morphological box and are specified in the following: The first dimension refers to the issue that some modeling scenarios demand for a *temporal dissolution* of modeling activities, such as the modification and visualization: Some scenarios only demand a sequential realization of modeling activities (*sequence*) and others demand to realize them simultaneously in one *moment*. The second dimension refers to the number of persons (*single persons* or *multiple persons*) currently modeling with a desktop, laptop, tablet or AR glasses. The third dimension refers to the question, if a *real-time capability* is required, or activities can be *recorded* and used in later sequences. The dimension is called *technical time capabilities* here. The fourth dimension refers to the number of devices (*single device* or *multiple devices*), which are required for the model creation. This focuses on modeling systems as active systems, which are separated from passive systems only visualizing information from active systems. The fifth dimension refers to the *interplay of the modeling worlds* having three parameters: Modeling worlds can be disconnected, such that models are exchanged only within the corresponding world (*no interplay*). Alternatively, modeling worlds are connected in one direction, such that an *unidirectional interplay* realizes exchanges from one world to the other. Only a *bidirectional interplay* realizes the exchange of modeling activities from 2D modeling world to 3D AR modeling world and vice versa without limitation.

Faced with the six modeling scenarios, the complexity and requirements for an implementation rise with every number. Hence, a stepwise implementation from the first to the last modeling scenario is recommended.

Summing up, *AR modeling modes* presented here serve for the derivation of a collection of requirements. Those will be part of the design of a bidirectional AR modeling.

5 Demonstration of an AR Modeling

The complex problem of designing an AR modeling is parametrized by a morphologic box. The morphologic box can be seen in Fig. 5 and shows dimensions considering design maxims identified previously as follows.

The *knowledge construction axiom* presented in Sect. 4.1 is considered implicitly by the meta-model for AR modeling (Sect. 4.2). This answers the question, which kind of modeling objects shall be considered in which world. *Use cases* identified in Sect. 4.3 are considered in order to answer the question, which kind of operations are required in which world. Here, operations are clustered to the categories *modeling*, *simulation* and *administration*. The *modeling modes* designed in Sect. 4.4 are considered in order to answer the question, which kind of background requirements are necessary in regard to modeling scenarios.

Parameters for each dimension are derived from basic control concepts presented in Sect. 2.3. In general, they are based on the use of a touch pad, eye

Origin	Dimension	Parameter					
Meta-Model for an AR Modeling	Modeling Object Focus	only time-based position related objects	perspective related objects	all objects			
Use Case Diagram for an AR Modeling (Modeling)	Choose Intended Shape	per cursor and touch pad activation from legend	per physical look on AR modeling belt	per voice recognition	per thoughts and unique shape denomination		
	Select Intended Shape	per cursor and touch pad activation	per visual contact and eye focus analysis	per voice recognition and unique shape denomination	per thoughts and unique shape denomination		
	Grab Intended Shape	per touch pad activation	per image analysis and grap movement	per eye blink pattern	per voice recognition	per thoughts about grab instruction	
	Position Intended Shape	per touch slide along axises	per movement within reality (sensory information, image analysis)	per voice recognition (axis and distance instructions)	per thoughts about position instruction		
	Drop Intended Shape	per touch pad activation	per image analysis and drop movement	per eye blink pattern	per voice recognition	per thoughts about drop instruction	
	Delete Intended Shape	per shape selection and delete button activation	per image analysis and delete movement	per eye blink pattern	per voice recognition	per thoughts about delete intended shape instruction	
	Connect Intended Shape	per cursor on connection visualization and touch pad activation	per relation object selection (see „choose intended shape")	per image analysis and connect movement	per eye blink pattern	per voice recognition	per thoughts about connect shapes instruction
	Zoom On Intended Shape	per cursor and touch pad activation using two fingers	per image analysis and zoom movement	per eye blink pattern	per voice recognition	per thoughts about zoom instruction	
	Modify Size of Intended Shape	per shape and axis selection and touch pad activation using two fingers	per image analysis and size modification movement	per eye blink pattern	per voice recognition	per thoughts about increase size instruction	
	Rotate Intended Shape	per shape and axis selection and touch pad activation using three fingers	per image analysis and rotate movement	per eye blink pattern	per voice recognition	per thoughts about rotate instruction	
	Undo	per button selection and touch pad activation	per image analysis and undo movement	per eye blink pattern	per voice recognition	per thoughts about undo instruction	
	Redo	per button selection and touch pad activation	per image analysis and redo movement	per eye blink pattern	per voice recognition	per thoughts about redo instruction	
Use Case Diagram for an AR Modeling (Simulation)	Start Simulation	per cursor on start button and touch pad activation	per image analysis and start movement	per eye focus on start button and blink pattern	per voice recognition of start instruction	per thoughts about start instruction	
	Pause Simulation	per cursor on pause button and touch pad activation	per image analysis and pause movement	per eye focus on pause button and blink pattern	per voice recognition of pause instruction	per thoughts about pause instruction	
	Stop Simulation	per cursor on stop button and touch pad activation	per image analysis and stop movement	per eye focus on stop button and blink pattern	per voice recognition of stop instruction	per thoughts about stop instruction	
	Next Time Step of Simulation	per cursor on next button and touch pad activation	per image analysis and next movement	per eye focus on next button and blink pattern	per voice recognition of next instruction	per thoughts about next instruction	
	Previous Time Step of Simulation	per cursor on previous button and touch pad activation	per image analysis and previous movement	per eye focus on previous button and blink pattern	per voice recognition of previous instruction	per thoughts about previous instruction	
Use Case Diagram for an AR Modeling (Administration)	Register	per digital keyboard and key selection (see „choose intended shape") in guided register process	per movement on key of digital keyboard and image analysis in guided register process	per eye focus on key of digital keyboard and blink pattern in guided register process	per voice recognition in guided register process	per thoughts in guided register process	
	Login	per digital keyboard and key selection (see „choose intended shape") in guided login process	per movement on key of digital keyboard and image analysis in guided login process	per eye focus on key of digital keyboard and blink pattern in guided login process	per voice recognition in guided login process	per thoughts in guided login process	
	Create New Model	per digital keyboard and key selection (see „choose intended shape") in guided create process	per movement on key of digital keyboard and image analysis in guided create process	per eye focus on key of digital keyboard and blink pattern in guided create process	per voice recognition in guided create process	per thoughts in guided create process	
	Load Model	per digital keyboard and key selection (see „choose intended shape") in guided load process	per movement on key of digital keyboard and image analysis in guided load process	per eye focus on key of digital keyboard and blink pattern in guided load process	per voice recognition in guided load process	per thoughts in guided load process	
	Save Model	per save buton selection (see „choose intended shape")	per movement on key of digital keyboard and image analysis in guided save process	per eye focus on save button and blink pattern in guided register process	per voice recognition and save instruction	per thoughts about save instruction	
Modeling Modes for an AR Modeling	Modeling Scenario Id	1	2	3	4	5	6
	Temporal Dissolution of Modeling Activities	Moments	Sequences				
	Number of Persons Modifying Models	Single Person Modeling	Multiple Person Modeling				
	Technical Time Capabilites	Record Capability	Real-Time Capability				
	Number of Devices Used for Modifying Models	Single Device Modeling	Multiple Device Modeling				
	Modeling World Interplay	No Interplay	Unidirectional Interplay	Bidirectional Interplay			
	AR Modeling Modes	Unidirectional-Interplay-Mode	One-Person-Mode	Collaboration Mode	Multiple-Device-Mode		

Fig. 5. Morphologic box for a bidirectional AR modeling.

focus analysis, voice recognition, image and video analysis, computer vision and thought detection. Parameters presented here do not attempt for completeness rather than provide a first approach for structuring and parametrize an AR modeling. Given a highly evolutionary technical environment and so far non-standardized hardware controllers, parameters of each dimension and dimensions of the morphologic box can be extended and modified easily. Hence, on base of a continual redesign of the morphologic box, an always uptodate and state-of-the-art, flexible framework can be constructed.

A selection of parameters for each dimension of the morphologic box serves as *configuration* of an AR modeling. An example configuration is given by yellow highlighted cells (Fig. 5). Using the morphologic box presented here, each configuration is suited for an application in an AR modeling tool, such as the *Augmentor* [3].

6 Evaluation

All in all, the morphologic box presented in Sect. 5 provides 132 different configurations. Each represents a working AR modeling characterization. Since this framework is designed to be flexible and changes in the contemporary environment, such as IT hardware developments and creative, new control concepts, will lead to further dimensions and parameters. This drastically increases the number of total configurations and with this the complexity to identify attractive configurations rises as well. The question remains, which of those configurations supports an AR modeling best and how best configurations can be identified easily.

Aiming to identify the configuration of the morphologic box, which realizes process modeling best in both worlds, the common 2D process modeling world and the 3D AR modeling world, an evaluation of available configurations can be carried out in two ways in accordance to Zwicky: First, a survey can be conducted in a workshop session with modeling experts, so that their majority acceptance can be identified for one configuration. Second, experiences can be collected based on the application of one morphologic configuration in a software and its use in modeling projects [22]. Here, an evaluation can either focus on this individual configuration and evaluate its practicability within realistic project settings, or it can focus on a comparison of a set of applied configurations. In a comparison of this set, the best configuration will show most attractive evaluation values.

Since an implementation of any configuration of the morphologic box here presented has not been realized yet, and the best configuration of this morphologic box will be implemented, the first evaluation approach is attractive and was carried out as described in the following:

Interviews have been held with a group of 63 individuals educated in Business Process Management (BPM) at the University of Potsdam for one semester. This includes students of all: economics, computer science and business informatics. The BPM module included a theoretical BPM education, the application of

Table 1. The fulfillment of design-science research guidelines

Guideline	Description
Guideline 1: Design as an artifact	The authors design a flexible framework for the definition of an AR Modeling within the common 2D process modeling world and the 3D AR modeling world. This is founded on the following sub artefacts: a knowledge construction axiom, a meta-model, a use-case collection and a modeling mode design. This framework is demonstrated in workshop sessions. A best configuration is identified that can serve for benchmarks with further AR modeling approaches
Guideline 2: Problem relevance	Considering the previously mentioned artifacts, the business problem of complex interplay of 2D modeling world and 3D AR modeling world is overcome by a simple configuration of a morphologic box. With this artefact, a common framework is presented that can serve for comparison with further AR modeling approaches, and be applied to different implementations. As the framework is parameter-based, the concrete framework around contemporary AR hardware and IT systems is reasonable, given a highly evolutionary technical environment and the continual application of the framework
Guideline 3: Design evaluation	The efficacy of the designed artifacts was demonstrated rigorously by means of surveys conducted in workshop sessions with modeling experts. The utility and quality of the morphologic box was demonstrated by the identification of a configuration with the most acceptance. The execution precisely followed the proceeding specified by [22]. Therefore, validation of the morphological box is valid within a first application, and will be implemented and used in larger projects and real-life settings as a next step
Guideline 4: Research contributions	The design-science contributions of this research are the proposed framework, its sub artefacts and evaluation results in the form of surveys conducted in workshops. These contributions advance our understanding of the manner in which to carry out AR modeling best
Guideline 5: Research rigor	Research on process modeling approaches has long been based on the 2D world. In this contribution, a multi dimensional, parameter-based framework provides the underlying integration strategy of the common 2D process modeling world and the 3D AR modeling world, which allows for efficient process modeling realizations (such as the modeling, sharing, cooperation and visualization) and enables the development of more context-specific modeling software, benchmarks, and applications in projects
Guideline 6: Design as a search process	As discussed previously, the implementation of AR modeling strategies, application in projects, and benchmarking in iterations is essential. The authors studied variations in realization strategies over a period of 7 months within the aforementioned workshops. Creativity and problem-solving capabilities were involved in the construction of this framework
Guideline 7: Communication of research	The presentation of this research is aimed at an audience familiar with process modeling theory, AR hardware and software implementation. Even so, the contribution provides useful information for managerial audiences. While the authors present a thorough discussion of sense-full configurations, the contribution provides evidence for both technical implementations and economic reasoning

five modeling languages in different modeling projects and the discussion about concepts presented here. In workshops, the acceptance per each dimension of the morphologic box was made subject to the discussion and a preference in regard to presented parameters and a practical implementation has been conducted.

Overall, that parameters were determined for each dimension, that showed the greatest acceptance. Considering Fig. 5, highlighted, yellow cells do not only represent an example configuration, as was mentioned in Sect. 5. They represent parameters with the greatest acceptance. Hence, highlighted cells can be interpreted as best configuration for an AR modeling so far.

7 Conclusion

In this paper, a flexible *framework for a bidirectional AR modeling* has been drawn. This supports the use of various modeling languages since it is derived from a *meta-model* for modeling languages. It considers state-of-the-art systems and various modeling domains since it follows the *knowledge construction axiom*. Further, basic operations and requirements are considered following typical *use cases* and *AR modeling modes*. Six design maxims were derived from those sub artefacts.

By the integration of all six design maxims into a morphologic box, a framework was presented that specifies an AR modeling systematically. With this, the first sub research question is answered (*"How can an AR modeling be specified systematically?"*). The conduction of the greatest acceptance per dimension of the morphologic box in a survey answers the second sub research question (*"How can process modeling be realized best in both worlds?"*). The configuration highlighted in Fig. 5 defines how a process modeling is realized best in both worlds. So, considering all artefacts and insights in regard to sub research questions, the main research question (*"How can processes be modeled within the augmented world?"*) can be answered effectively: In accordance with the design-science research guidelines of Hevner et al., this contribution satisfies the requirements for effective design-science research and is complete [4], as it is indicated in Table 1.

This table presents seven design-science research guidelines and describes how presented artefact and this contribution satisfies them. Presented insights and research contributions have to be limited in so far as artefacts only have been validated by surveys conducted in workshop sessions. This is satisfying for now, since an implementation of the best AR modeling configuration in modeling tools is still missing.

Therefore, next steps will focus on an implementation of the best AR modeling configuration identified here and its application in various modeling projects, such that the main research question can be answered in a statistical satisfying manner.

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