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Collaborative Modeling of Use Case & Damage Scenarios in Online Workshops Using a 3D Environment

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Abstract

The development of technical systems requires close cooperation of stakeholders from different disciplines. This collaboration takes place in workshops. Driven by digitalization and by the current pandemic such workshops take place primarily online. Suitable collaboration tools and methods are crucial to success. At the beginning of such workshops, use and damage scenarios are identified. In this paper, we presented a method and tool for identifying and modeling use and damage scenarios, which we evaluated in 14 online workshops with a total of 118 participants over a period of almost 3 years.

Keywords: *collaborative design, online-workshops, 3D modelling, behavioural design, multi-/cross-/trans-disciplinary approaches*

1. Introduction

The development of intelligent technical systems, such as autonomous vehicles, is characterized by close collaboration between different disciplines such as mechanical engineering, electrical engineering, and software engineering (Gausemeier et. al., 2014). The cooperation can also extend across different companies, suppliers, and subsidiaries, as is common in the automotive sector (Anacker et al., 2021, Japs, 2020).

At the beginning of product development, different use cases for the system to be developed are identified during the concept phase. The identification of such use cases is done collaboratively in workshops with different stakeholders. The goal is the formation of a general overall understanding.

The overall understanding is achieved through the identification of use cases, the system delimitation, and the creation of a general system architecture (ISO, 2021) The stakeholders contribute to the overall understanding between all workshop participants through their expertise. It is important to maintain the appropriate level of abstraction in the concept phase; discipline-specific details make common understanding more difficult (Anacker et al., 2021). In the context of workshops at the concept level, top executives typically participate or subject matter experts on specific topics are additionally invited (Japs, 2020). Different drivers shape collaboration in workshops. Increasing digitization enables stakeholders from different locations and time zones to work together in online workshops using collaborative tools. At the same time, the German government defines home office as the primary choice of work location in the current pandemic (Federal Government Germany, 2021), so online workshops are practically often the only choice for collaboration. In addition to the use cases, damage scenarios can already be identified and processed in the concept phase (Japs, 2020, Anacker et al. 2021, Anacker & Japs 2021). ISO/SAE 21434 (ISO, 2021) defines as follows: A Damage Scenario is an adverse consequence affecting a vehicle or a vehicle function that affects a road user (E.g., passenger, pedestrian, or vehicle owner). ISO/SAE 21434, which is relevant to the automotive sector, even requires that damage scenarios are considered in the concept phase. Crucial for successful collaboration in online workshops is the choice of the right tools in combination with an appropriate approach. Complicated tools make it difficult to get started, while an unclear or overly comprehensive approach hinders collaboration (Anacker, 2021; Japs, 2021).

In the context of this work, we have analyzed different collaboration tools for use in the concept phase for use in online workshops according to different categories and requirements (see Section 2 for a detailed analysis). Here, we can generally divide the tools into 2D-based and 3D-based tools. The 2D tools offer the advantage that they are easy to understand and use and thus use cases and damage scenarios can be quickly noted and discussed in the online workshop. The disadvantage is that these tools do not address the three-dimensional imagination of the workshop participants. Trying out the sequences and interrelationships of the use cases and damage scenarios is not supported visually. This shifts the identification of impediments to realization to subsequent phases of product development, resulting in higher coordination efforts. In contrast to this, 3D tools exist that address the imagination of the stakeholders and partially allow a trial and error of the sequences. The disadvantage of these tools is that they can only be used by trained experts such as simulation experts or CAD developers. This hinders the use of these tools in online workshops with interdisciplinary stakeholders. 3D tools mostly produce results that can be directly reused in subsequent steps of product development, while 2D tools usually do not allow reuse of results without manual conversion.

In this work, we present a tool that is 3D-based and thus enables three-dimensional visual support while being usable by untrained participants in online-workshops (cf. Section 3). Our work represents an extensive extension for a prototype we created and did not evaluate before (Japs et al., 2020).

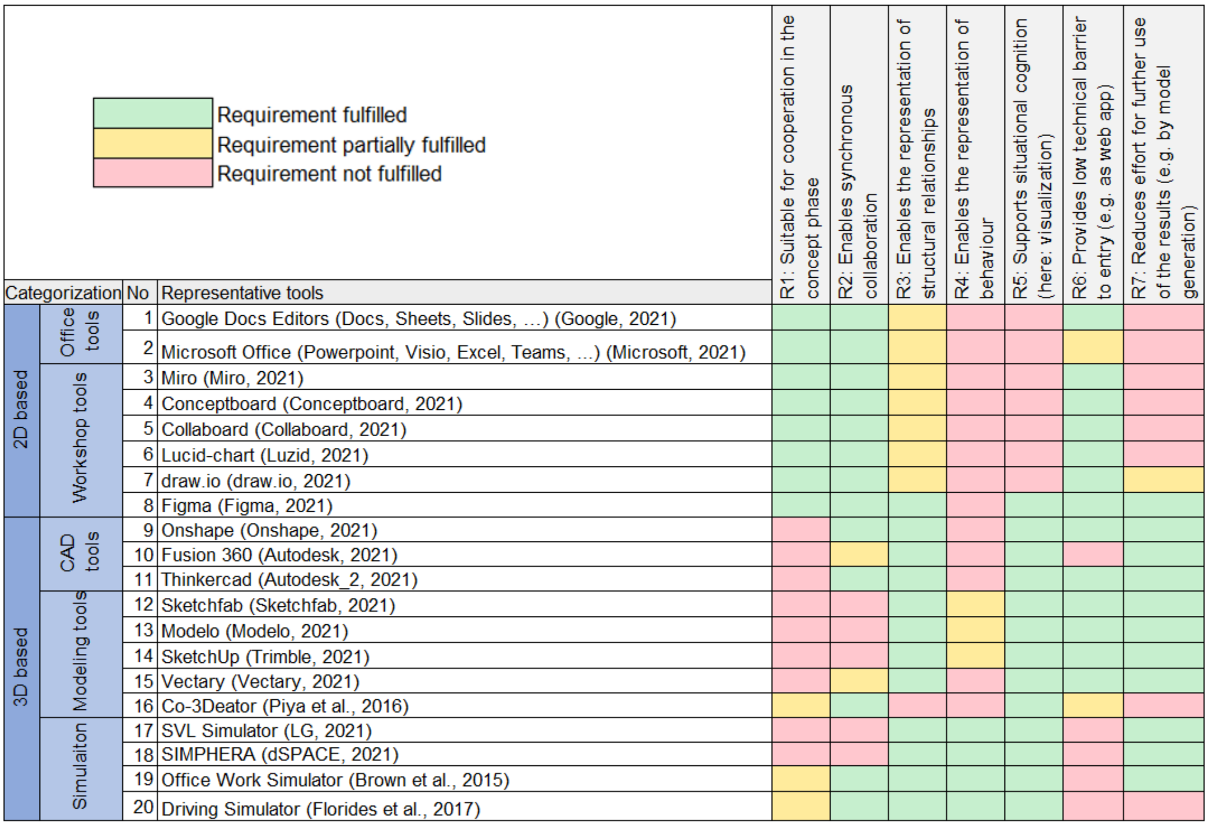
Furthermore, our tool creates a description of a corresponding SysML model in the background without requiring SysML knowledge from the stakeholders. The model generation reduces the manual conversion effort, and the workshop results can be directly used in professional modeling tools. For the systematic development of workshop results we present a dedicated method, which is based on steps of Design Thinking (Gumienny et al., 2010). Furthermore, we report on the numerous workshops we held with different participants during the last 3 years. In these workshops we were able to identify necessary features for our tool and gaps in the methodical approach (see Section 4).

Our approach is based on our experience as workshop moderators in industry and research projects. Basically, this is subjective, therefore other individuals would draw different conclusions and develop different tools. However, we fundamentally assume that images and 3D scenes of use and damage scenarios are often more informative than merely auditive or textual based notations.

2. Analysis of related approaches

In this section, we present a categorization and an evaluation of the tools we analyzed. We make a basic distinction between 2D- and 3D-based tools and conclude that a tool is needed that combines the advantages of both types. We divide the 2D-based approaches into Office tools and Workshop tools. Office tools are primarily used to create documents such as slides, texts, and tables. Workshop tools primarily serve as a digital whiteboard, these tools use 2D shapes like rectangles, circles etc. for visual communication which can be connected to each other. 3D based approaches we divide into CAD tools, 3D modeling tools and 3D simulation tools. CAD tools enable exact geometric modeling. Among other things, they can be used to check concepts geometrically at an early stage, and they can also be used to create models as a basis for production. 3D modeling tools focus on visualization. This makes it easier to create models for the visualization of prototypes. With 3D simulation tools complex processes can be tested and visualized. By posting Figure 1 (without full rating) in a career network (1425 views, 10 comments), we could determine that the categorization predominantly covers tools for concept development.

In the following, we describe the requirements according to which we examined the different tools. The requirements are based on our experience in using different online collaboration tools with industry and research partners. The requirements generally address the level of support for collaboration among different stakeholders in online workshops. (R1) Online collaboration tools for use in the concept phase must not require in-depth expertise for use, e.g., knowledge of geometric modeling or knowledge of modeling simulation processes. We justify this by pointing out that the common professional basis of interdisciplinary stakeholders is low. (R2) Online collaboration tools must enable simultaneous editing of a document, environment, etc., to enable parallel work and thus active collaboration of multiple participants. This contrasts with the rather one-sided collaboration in the form of a presentation of results in an online meeting. To illustrate complex structures (R3) or complex interactive sequences (R4), online collaboration tools must provide suitable means and functionalities. Creating structural relationships in concept development is fundamental. If one must identify use and damage scenarios that represent behavior, an associated tool must also enable the modeling of behavior. (R5) To enhance visual contexts, online collaboration tools must provide visualization. (R6) Online collaboration tools must be immediately usable without technical hurdles and independent of department and company. When stakeholders of a company or several companies from different disciplines collaborate online, different IT infrastructures exist with different rights concepts for the application of software. To ensure that collaboration does not fail due to unsuitable application software, the application software must be usable from any operating system, any location, web browser with minimal requirements for the rights concept. (R7) In order to be able to continue using results outside of online workshops, online collaboration tools must have an export function that enables further processing of the results on a fine-granular basis. This means that an image or PDF export is not sufficient, which some of the analyzed tool's offer.

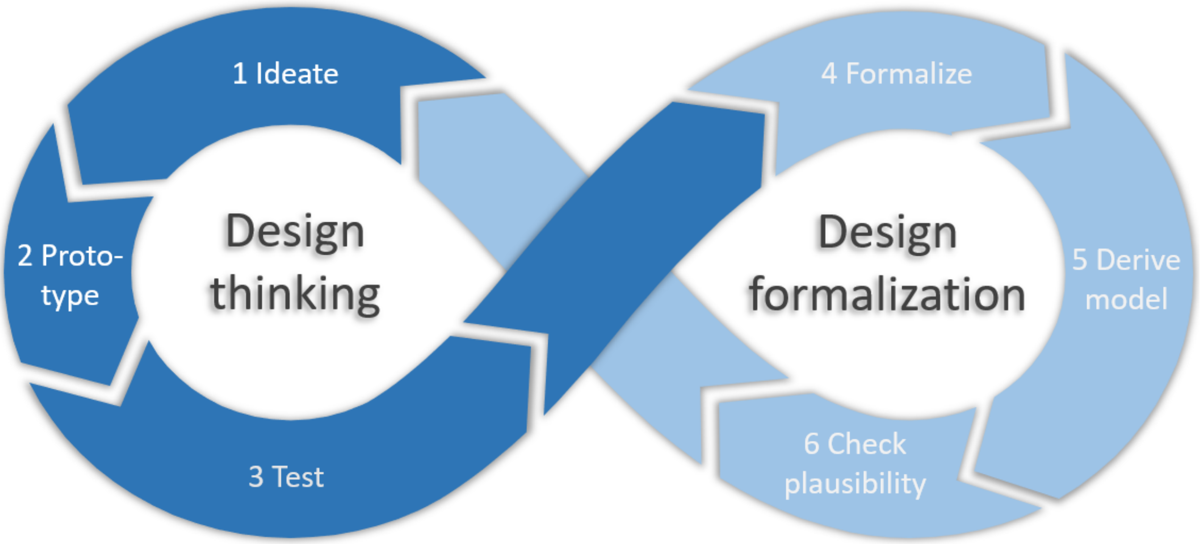


🟩 Requirement fulfilled
🟨 Requirement partially fulfilled
🟥 Requirement not fulfilled

Categorization		No	Representative tools	R1: Suitable for cooperation in the concept phase	R2: Enables synchronous collaboration	R3: Enables the representation of structural relationships	R4: Enables the representation of behaviour	R5: Supports situational cognition (here: visualization)	R6: Provides low technical barrier to entry (e.g. as web app)	R7: Reduces effort for further use of the results (e.g. by model generation)
2D based	Office tools	1	Google Docs Editors (Docs, Sheets, Slides, …) (Google, 2021)	🟩	🟩	🟨	🟥	🟥	🟩	🟥
		2	Microsoft Office (Powerpoint, Visio, Excel, Teams, …) (Microsoft, 2021)	🟩	🟩	🟨	🟥	🟥	🟨	🟥
	Workshop tools	3	Miro (Miro, 2021)	🟩	🟩	🟨	🟥	🟥	🟩	🟥
		4	Conceptboard (Conceptboard, 2021)	🟩	🟩	🟨	🟥	🟥	🟩	🟥
		5	Collaboard (Collaboard, 2021)	🟩	🟩	🟨	🟥	🟥	🟩	🟥
		6	Lucid-chart (Luzid, 2021)	🟩	🟩	🟨	🟥	🟥	🟩	🟥
		7	draw.io (draw.io, 2021)	🟩	🟩	🟨	🟥	🟥	🟩	🟨
		8	Figma (Figma, 2021)	🟩	🟩	🟩	🟥	🟩	🟩	🟩
3D based	CAD tools	9	Onshape (Onshape, 2021)	🟥	🟩	🟩	🟥	🟩	🟩	🟩
		10	Fusion 360 (Autodesk, 2021)	🟥	🟨	🟩	🟥	🟩	🟥	🟩
		11	Thinkercad (Autodesk_2, 2021)	🟥	🟩	🟩	🟥	🟩	🟩	🟩
	Modeling tools	12	Sketchfab (Sketchfab, 2021)	🟥	🟥	🟩	🟨	🟩	🟩	🟩
		13	Modelo (Modelo, 2021)	🟥	🟥	🟩	🟨	🟩	🟩	🟩
		14	SketchUp (Trimble, 2021)	🟥	🟥	🟩	🟨	🟩	🟩	🟩
		15	Vectary (Vectary, 2021)	🟥	🟨	🟩	🟥	🟩	🟩	🟩
		16	Co-3Deator (Piya et al., 2016)	🟨	🟩	🟥	🟥	🟩	🟨	🟥
	Simulaiton	17	SVL Simulator (LG, 2021)	🟥	🟥	🟩	🟩	🟩	🟥	🟩
		18	SIMPHERA (dSPACE, 2021)	🟥	🟥	🟩	🟩	🟩	🟥	🟩
		19	Office Work Simulator (Brown et al., 2015)	🟨	🟩	🟩	🟩	🟩	🟥	🟩
		20	Driving Simulator (Florides et al., 2017)	🟨	🟩	🟩	🟩	🟩	🟥	🟥

Figure 1. Analysis and evaluation of the examined approaches

In the following, we will go into detail about some of the approaches examined. Microsoft Office is suitable for creating Office documents. Documents can be edited by several users at the same time without any training effort. Shapes such as rectangles can be used to create structures with the help of connecting lines. Creating complex interactive sequences is not possible. Those who do not have Office can edit documents in the browser via an invitation link, but the display is not the same or error-free as the native application. An editable export in a non-Office tool is not possible. Onshape is a CAD tool. CAD models can be viewed and moved by different stakeholders. However, editing and creating CAD models requires specific expertise. The tool can be used collaboratively. Each CAD model consists of individual parts, allowing complex structures to be created. As a web tool, access is simple. Created CAD models can be reused in further tools. SIMPHERA is a 3D simulation tool for testing critical situations in road traffic. Simulations can be viewed by different stakeholders but creating and editing simulations requires specific expertise. The tool cannot be used collaboratively. Complex structures and processes can be modeled. Tool access requires lengthy preparation through installation and potentially requires installation rights approval by system administrators. Simulation results can be reused in other tools.



1	Which use cases and damage scenarios are relevant for the system to be developed?
	How do you rate the priority of each case?
2	Which 3D objects do you need to visualize a case and how do the 3D objects relate to each other?
3	What important sequences does the selected case contain?
	What impediments do you notice when going through the case?
	What needs to be changed or added so that the sequence can be realized without problems?
4	How would you describe the case textually?
	How could you describe the process in more detail using the identified 3D objects?
5	Use the information obtained to derive SysML models.
6	Would you still understand the case description you created and the model relationships you identified in X weeks?

Figure 2. General procedure and supporting guiding questions for the workshop moderator

3. Solution approach

In this section we present a method in which context our tool 3D Engineer was used. The method is the result of numerous workshops conducted (see Section 4). Our method extends the CONSENS method (Gausemeier et. al., 2014), which is an approach from Model-Based Systems Engineering. The CONSENS method supports the workshop moderator in creating different structural and behavioral models. This also includes the creation of scenario visualization. In our approach we show how our developed tool can be applied in the scenario visualization. Furthermore, we describe how damage scenarios can be derived from application scenarios and how these are connected in terms of modeling. The method is based on our experience as workshop moderators and the feedback of the workshop participants. The workshop moderator uses our method to guide the participants through the steps to achieve a step-by-step extension and refinement of the results. For this purpose, the workshop moderator uses guiding questions that support the process (see Figure 2).

Our method consists of two parts. We illustrate the method and the use of 3D Engineer based on the outcome of the online workshop we moderated with 7 product development subject matter experts (see Figure 3 and Section 4). Part 1 serves to determine the expertise of the workshop participants. This requires their active participation in the workshop. Part 2 serves to formalize the workshop results for use in further steps of product development (e.g., requirements engineering/architecture design). A subset of the workshop participants is sufficient for formalization.

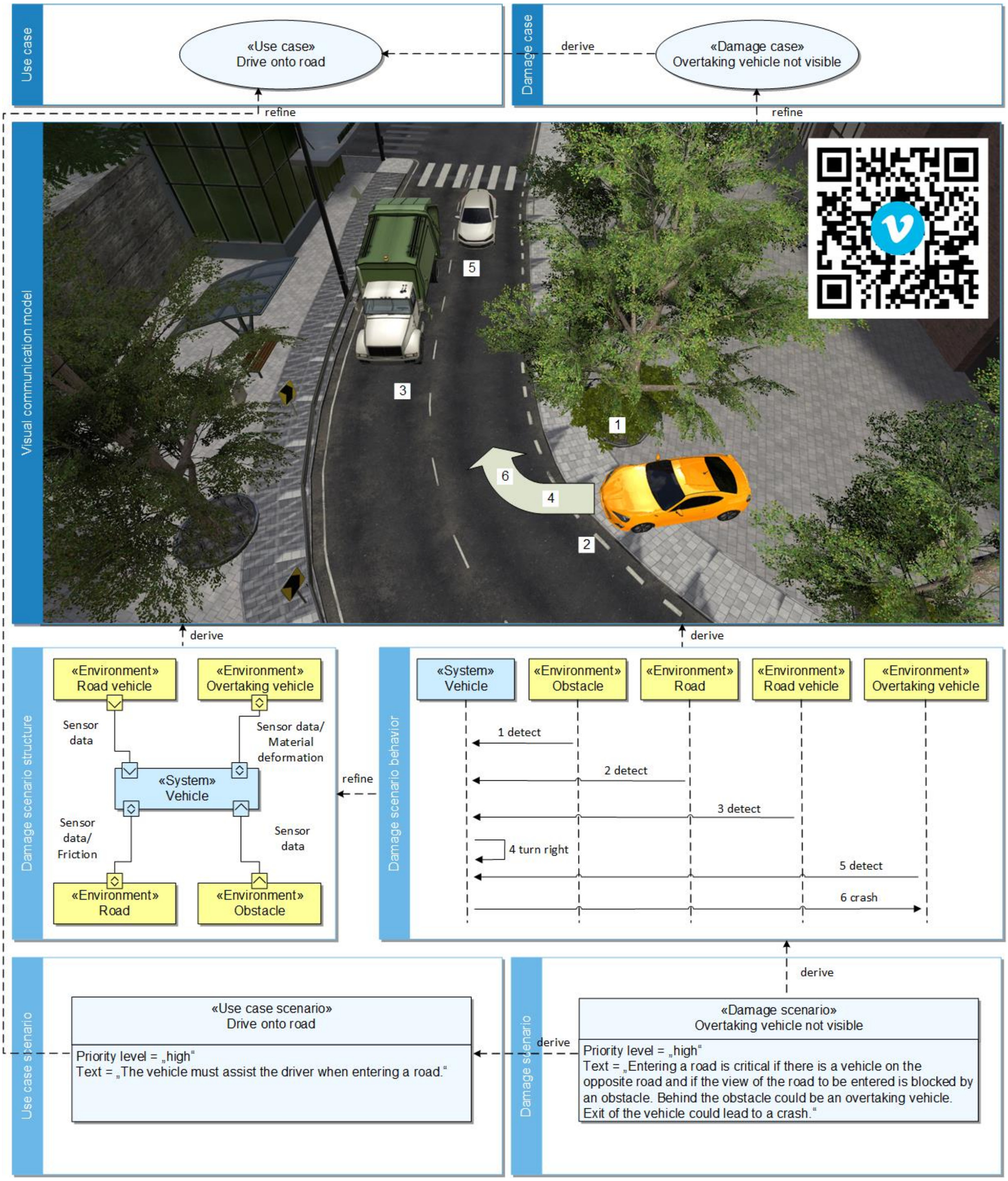


Figure 3. Result of the online workshop with 7 experts from the field of product development

In Part 1, we use process steps from Design Thinking (Gumienny, 2010). We focus on the steps Ideate, Prototype and Test. In Step 1 (Ideate), use cases and potential damage scenarios are identified, noted in short form, and discussed. For this purpose, e.g., the 2D-based workshop tools mentioned in Section 2 can be used. Based on the discussion, a general understanding between all workshop participants is ensured. To use the limited time frame of the workshop participants effectively, use cases and damage scenarios must be prioritized so that only relevant cases are further processed. In the workshop mentioned above, the participants focused on the use case "Drive onto road" and derived the damage case "Overtaking vehicle not visible". Step 3 (Prototype) is used to visualize use cases and damage scenarios. For this purpose, the participants use 3D Engineer. First, necessary 3D objects for the use case must be identified and placed in 3D Engineer. By moving the 3D objects, the behavior of the use cases or damage scenarios can be communicated between the workshop participants in Step 4 (Test). In the workshop, participants modeled the case shown in Figure 3 (Visual communication model). By moving the 3D objects, the participants constructed several sequences and finally identified a concrete damage scenario. Part 2 involves formalizing the use case to ensure usability of the results outside of the workshop. This step was performed with a subset of the workshop participants. In Step 4 (Formalize), the discussed case is formalized based on the experiences in the Prototype and Test steps. This is done by describing the object relationships and the sequence steps in our tool. Furthermore, the explicit formulation of the use case and the corresponding damage case is done in some short sentences. In the example (damage case): "Entering a road is critical if there is a vehicle on the opposite road and if the view of the road to be entered is blocked by an obstacle. Behind the obstacle could be an overtaking vehicle. Exit of the vehicle could lead to a crash". In Step 5 (Derive model), our tool supports users by automatically deriving SysML models. We chose SysML (OMG, 2015) as the modeling language because it is one of the de facto modeling languages in systems engineering (Dori, 2016). Our tool generates a black-box structural model from the object relationships in the form of a SysML IBD. Based on the information about the sequence, our tool generates a black-box behavioral model in the form of a SysML sequence diagram. In Step 6 (Check plausibility), a final quality check is performed to ensure the usability of the results outside the workshop. During Step 6, the results can be reviewed by other employees or a report can be presented to other employees.

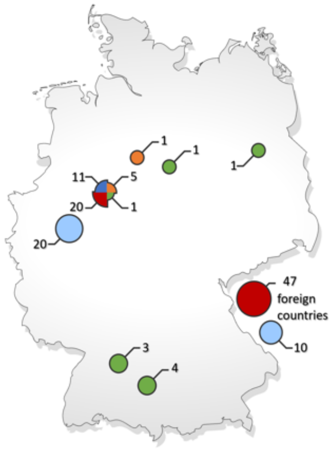
4. Evaluation

In this section we describe how, and in which form we have evaluated our approach. Over a period of almost 3 years, we conducted several online workshops with different groups of participants, in which we applied and continuously improved 3D Engineer in conjunction with our method (see Figures 4 and 5). The participants were from different places, countries, and continents. The development of the tool was done in the context of 4 student theses, a project work with 3 students over one year and continuously with two additional student assistants. Our role in the development of 3D Engineer consisted in the beginning, in the creation of a Proof-Of-Concept (Japs et al., 2020), while we subsequently led the development and constantly tested the usability of the tool. For easy and fast use of our tool, we have additionally examined 10 of the 20 examined approaches in Section 2 regarding usability. We developed the corresponding method ourselves. Furthermore, we led all 14 workshops as moderators. In the workshops of the Development Team, we additionally assumed the role of workshop participants. In Figure 4 we have presented a characterization of the different workshops. Basically, the workshops in the teaching area served as preparation for using our approach with subject matter experts. In addition to regularly discussing the progress of our approach with research partners, we regularly presented our approach to a German car manufacturer to ensure the practicability of our approach.

Over a period of almost 3 years, 10 online workshops and numerous additional coordination and planning meetings with the development team took place. During the preparation of the first workshops, the basic version of our method was developed. The starting point for the tool was the proof-of-concept implementation (Japs et al., 2020) that we had developed but had not evaluated before. This version was basically not suitable for use in online workshops (R1-R6 not satisfied). In the first workshops with the development team, we found that specific 3D objects are not available without hurdles (e.g., not free, complicated conversion required). For this reason, we have developed a plug-in that allows in a few steps to create missing 3D objects in a simplified form using voxel blocks.

This development status (R2 and R6 not fulfilled) served as a basis for a full-day Summer School online workshop and a 2.5-day online project workshop with master students from the field of computer science & engineering. Due to the large number of participants in both workshops, the elaboration of the results took place in group work. In each case, one group participant used our tool, while the other group participants contributed information to the modeling.

To improve immersion, an extension for use with VR hardware was developed experimentally for Occulus Quest (Meta, 2021). The immersion effect was impressive, as one could virtually move around the 3D environment from both a first person and bird's eye view. Since online workshop participants typically do not have such hardware available, we did not continue development on this extension. However, we see added value for this extension in locally co-located workshops where the VR hardware is brought by the workshop organizers.



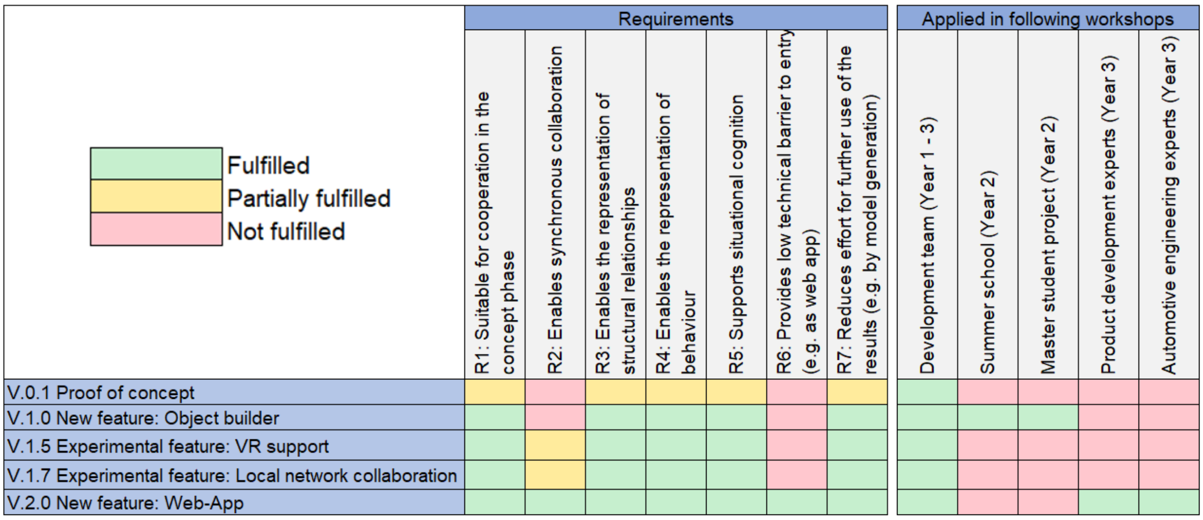
Geographical distribution of all 118 online-workshop participants

		Time	No of workshops	No of participants (average)	Identified use case scenarios (average)	Identified damage case scenarios (average)	Average workshop duration (h)	Workshop time per category (h)	Identified use cases or damage case scenarios /h	Design thinking steps considered	Design formalization steps considered
Teaching	Development team	Year 1-3	10	4	1	1	2	80	1	yes	yes
	Summer school	Year 2	1	30	14	14	8	240	3,5	yes	yes
	Master student project	Year 2	1	67	110	120	20	1340	11,5	yes	yes
Industry & research	Product development experts	Year 3	1	7	1	1	1	7	2	yey	no*
	Automotive engineering experts	Year 3	1	10	2	2	2	20	2	yes	no*

*This was done afterwards by workshop organizers

In total, our tool and our method were applied in 14 workshops. The result is 266 modelled use case and damage case scenarios and associated derived models. We could test our appraoch in a total of 10,5 person-months (1 PM = 8h*20 days).

Figure 4. Characteristics of the workshops conducted



🟩 Fulfilled
🟨 Partially fulfilled
🟥 Not fulfilled

	Requirements							Applied in following workshops				
	R1: Suitable for cooperation in the concept phase	R2: Enables synchronous collaboration	R3: Enables the representation of structural relationships	R4: Enables the representation of behaviour	R5: Supports situational cognition	R6: Provides low technical barrier to entry (e.g. as web app)	R7: Reduces effort for further use of the results (e.g. by model generation)	Development team (Year 1 - 3)	Summer school (Year 2)	Master student project (Year 2)	Product development experts (Year 3)	Automotive engineering experts (Year 3)
V.0.1 Proof of concept	🟨	🟥	🟨	🟨	🟨	🟥	🟨	🟩	🟥	🟥	🟥	🟥
V.1.0 New feature: Object builder	🟩	🟥	🟩	🟩	🟩	🟥	🟩	🟩	🟩	🟩	🟥	🟥
V.1.5 Experimental feature: VR support	🟩	🟨	🟩	🟩	🟩	🟥	🟩	🟩	🟥	🟥	🟥	🟥
V.1.7 Experimental feature: Local network collaboration	🟩	🟨	🟩	🟩	🟩	🟥	🟩	🟩	🟥	🟥	🟥	🟥
V.2.0 New feature: Web-App	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟥	🟥	🟩	🟩

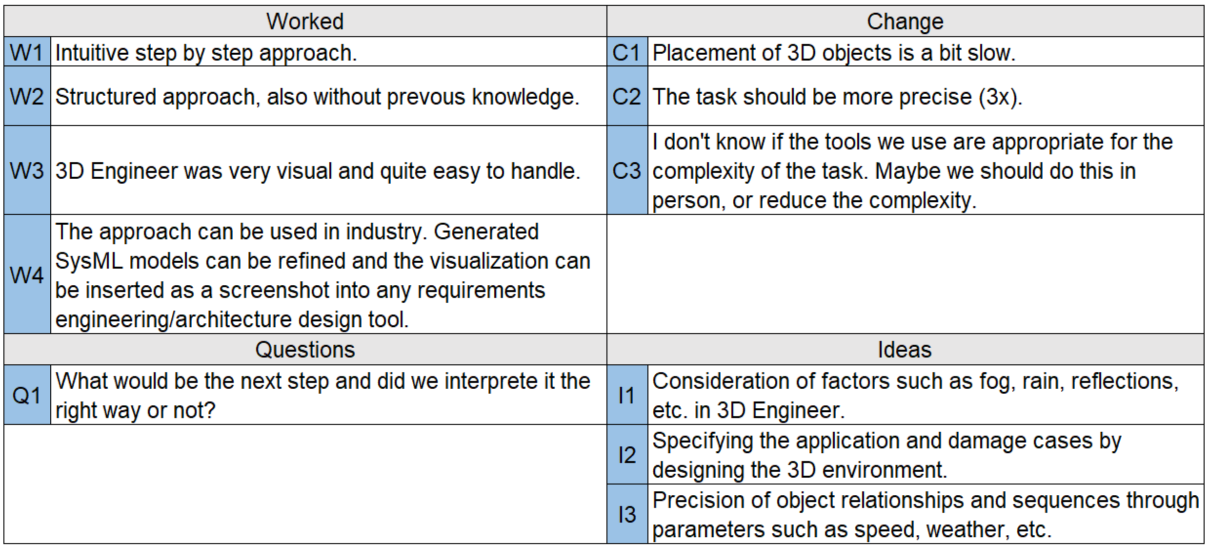
Figure 5. Derivation of necessary/experimental features to improve 3D Engineer

Enabling simultaneous elaboration (fulfillment of R2) of use cases and damage scenarios within 3D Engineer was done in two stages. In Stage 1, the focus was on developing functions for simultaneous operation of the 3D environment by multiple participants (simultaneously placing/moving objects, blocking simultaneous editing, etc.). We tested this in development workshops in a defined network. In Stage 2, the focus was on network-independent (and thus primarily location-independent) simultaneous use of our tool. This leads to the fulfillment of R6 through a cloud solution, Photon Unity Networking 2 (Unity technologies, 2021). To ensure a broad and platform-independent use of our tool, we have decided to further develop it as an app in the web browser that can be called through a web link. For this we use WebGL (Khronos, 2021), because it allows to display 3D graphics without technical barriers in the browser.

This stage of development was the condition for the two concluding expert workshops. The reason was that in the current pandemic, the participants worked almost exclusively in the home office and thus at different locations and in different networks and with different platforms. In Figure 6, we present the feedback from the participants in the expert workshops.

In general, our approach was well received by the 17 experts (see Figure 6, W1-W4). We would like to highlight W4 "The approach can be used in industry. Generated SysML models can be refined, and the visualization can be inserted as a screenshot into any requirements engineering/architecture design tool." We can easily fix C1 by limiting the use of very detailed 3D models. C1 is additionally dependent on the available bandwidth of each workshop participant. C2 was mentioned three times. The reason for this is that we used only verbal moderation for each step. A solution for this would be the use of a workshop canvas in a 2D workshop tool (see Section 2) in which the individual steps and the required artifacts would be described in detail. Additionally, supported by a simple example for each step.

Alternatively, 3D Engineer could guide users step by step in the creation of the 3D scenarios. However, we see here the danger of limiting creative elaboration, which often does not follow a strict flow. C3 is partly related to C2. The online workshop can also be conducted as a face-to-face workshop, but in our cases, 2 days of travel to and from the workshop would be necessary for some workshop participants. This is in contradiction to the limited time of the workshop participants in the daily project business. I1-I3 are suggestions for the extension of 3D Engineer. We consider all extensions to be useful for future work, although in the case of I2 the effort/benefit ratio in 3D modeling must be given special consideration.



	Worked		Change
W1	Intuitive step by step approach.	C1	Placement of 3D objects is a bit slow.
W2	Structured approach, also without prevous knowledge.	C2	The task should be more precise (3x).
W3	3D Engineer was very visual and quite easy to handle.	C3	I don't know if the tools we use are appropriate for the complexity of the task. Maybe we should do this in person, or reduce the complexity.
W4	The approach can be used in industry. Generated SysML models can be refined and the visualization can be inserted as a screenshot into any requirements engineering/architecture design tool.		
	Questions		Ideas
Q1	What would be the next step and did we interprete it the right way or not?	I1	Consideration of factors such as fog, rain, reflections, etc. in 3D Engineer.
		I2	Specifying the application and damage cases by designing the 3D environment.
		I3	Precision of object relationships and sequences through parameters such as speed, weather, etc.

Figure 6. Feedback from the 17 participants in the two experts' workshops

5. Conclusion

In this paper, we presented a method and tool for identifying and modeling use cases and damage scenarios, which we evaluated in 14 online workshops with a total of 118 participants over a period of almost 3 years. The main driver for the online orientation was the current pandemic.

We categorized 20 2D-based and 3D-based tools and evaluated them with respect to specific requirements. The requirements address aspects for the successful use of collaboration tools in online workshops for the creation of use cases and damage scenarios.

As part of this work, we developed an easy-to-understand and use tool that enables collaborative modeling of use and damage scenarios in a 3D environment. For easy use across company boundaries, we have developed the tool as a web app.

In this paper, we characterized the workshops we conducted with respect to several aspects and described the feedback-oriented development. Basically, the workshops in the context of teaching served as preparation for the two final workshops with a total of 17 subject matter experts. Using the outcome of one expert workshop as an example, we presented our method and tool. Furthermore, we summarized the feedback from the two expert workshops and then formulated our planned steps.

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