

Presentation and Quiz Visualization of Virtual Procedure Manuals

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Abstract

Virtual manuals for the usage of different procedures require a certain set of steps, for the users to familiarize themselves with the procedures required to use a set of desired objects. Apart from the textual information, it is also important to present different types of spatial information at the same time, while also including the direction of this type of information. Usually, a set of operations needs to be visualized by presenting the key locations of the operations, the order of operations, and their motion. Some operations require pulling, twisting, pushing, pressing, or some combination of these motions in different places at the same time. It is often important to test how much the user learned about all of the presented operations, to verify that the user can operate the procedure safely and successfully without supervision. In this paper, we analyze different visualization methods for multiple types of information by using animated 3D arrows. These arrows can present information by using gradient colors, shapes, sizes, and rotations of shapes, as well as shape animations in the desired direction. The proposed approach was successfully applied to create a virtual usage manual for a set of operations of a procedure. A virtual quiz that verifies whether the user learned all of the required steps was created. The quiz also requires the user to visually show the required operation motion. A small user survey was conducted, indicating that younger, highly educated age groups are more open to the usage of virtual manuals and that users find virtual quizzes helpful but are not confident that they possess the digital skills necessary for undertaking them.

Keywords: Virtual Reality in Education, Intelligent Tutoring Systems, 3D UI

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1 Introduction

The fast advancement of technology has enhanced our everyday lives in multiple aspects, from the near-instant availability of huge amounts of data to the complex user interfaces of web-applications offering business and customer service. One such aspect is the virtualization of objects and the development of simulation environments [2] that allow users to execute safety-critical programming code without endangering themselves, the objects of operation, or their surroundings. Apart from being able to design, implement, and test various products virtually, it is also possible to learn how to use them without owning or having access to the physical copy of the given product, which eliminates the possibility of breaking the product or getting hurt due to misuse. This can be especially useful for rare or very expensive products that require long training time (e.g. flight simulators) or are very fragile and require special care (e.g. chemistry or medical equipment).

User manuals [13] contain detailed information about products and their functionalities, as well as sets of instruction steps for their operation. The high amount of details, however, makes user manuals very long and therefore hard to perceive by customers, which is why the usage of visual information conveyed by images is very important for customer satisfaction [18]. The quality of the user manual is correlated with the quality of the product by customers [6], which is why companies need to properly convey important information about the usage of the product for the product to be accepted well. The study conducted by Tsai et al. [16] showed that a very high number of older adults often use product manuals and are willing to learn new technologies and use additional training materials. This indicates that the usage of the newest trends to convey information about the correct usage of products in a fast and straightforward way is suitable for all age groups and should be adopted to improve customer satisfaction.

In recent years, virtual reality (VR) and augmented reality (AR) technologies were introduced into training and assistance systems [9] as help and support to technicians. Different types of solutions have different strengths and

weaknesses, as discovered in a study by Laviola et al. [8], enabling the production companies to choose the type of technological solution that suits the type of their product the most. However, virtual product manuals usually convey information textually, without using the full potential of the technologies used to create them. This work presents a new approach that takes into consideration the type of information users are expected to learn through different product manuals. A method that uses various types of arrows for visualizing multiple types of information at the same time successfully is presented, without confusing the user with lots of text that is difficult to understand and hard to memorize.

The proposed approach was applied to a use case that simulates various types of instructions for the usage of an example product a user is expected to learn, to demonstrate the ease of presenting information by visualizing them instead of by using textual fields. A quiz mode in the virtual environment is also proposed to test the knowledge of the user about the learned procedure. However, in order to avoid the user mechanically learning the answers to the questions, randomization and different difficulty levels are used, utilizing the strengths of parametrizing the proposed virtual arrows and hand objects. This approach entirely removes the textual information from virtual product manuals and quizzes about their usage to reduce their complexity and improve the ease of their understanding by customers.

This paper is structured in the following way: Section 2 describes the background and related work for virtual product manuals, Section 3 introduces the proposed ways of visualizing different types of information in virtual environments, Section 4 contains the results of applying the proposed approach on an example use case containing a set of ten steps for operating a procedure, whereas Section 5 summarizes the achieved results and gives directions for future work.

2 Background

Several works propose the usage of VR applications as an alternative to traditional training manuals, mainly due to safety concerns and a possible lack of required equipment. Tichon and Scott in [15] compared the use of VR in safety training to a *PowerPoint* presentation. They showed that the usage of VR might provide more effective training because the group of users that was trained by using VR materials gained higher performance scores after their knowledge and skills in identifying manual handling hazards were tested. AlAwadhi et al. [1] presented a VR application for educational purposes such as practical learning and performing live experiments in engineering and science. This application was meant to help students practice dangerous experiments safely, avoiding risks and problems due to lack of access to equipment. De Lorenzis et al. [10] presented a Virtual Reality Train-

ing System (VRTS) designed to train first responders in the high-capacity pumping procedure. Participants reacted positively to the application and the overall quality of the training experience improved, as shown by the scores of the quiz session that showed a knowledge gain associated with the use of the VRTS. Kind et al. [7] presented an architecture that enables engineers to perform virtual assembly simulation with force feedback in a VR environment. This architecture is the basis of a testbed for conducting virtual assembly simulations.

The previously mentioned approaches rely on the usage of VR technologies that are expensive, require specialized equipment, and mostly cannot be used from home by most customers. Several approaches have therefore turned to AR technologies that are much easier to use and available to a large number of customers, such as Ferrati et al. [5] (for assembling hydraulic hoses for cherry picking) or Xue et al. [17] (for assembling and maintaining avionics equipment). A study by Dorloh et al. [4] showed that when comparing the usage of printed manuals, video guides, and AR technology, the speed of using an AR-enhanced manual was slow, but the quality of the performed task was the best. However, regardless of whether AR or VR technologies are used for enhancing the product manuals, the information is mostly textually presented, or at best by using highlight colors and shapes, as well as virtual hands to depict the user that operates the product. In a study conducted by Pekerti [12], the usage of pictures and arrows in an operation instruction set improved the success of performing the given task, indicating that arrows convey unique types of information and need to be used as instructional objects in user manuals.

3 Proposed approach

The proposed approach for creating virtual manuals contains two modes that will be described in detail in the following paragraphs.

3.1 The procedure presentation mode

In the presentation mode, the user cycles through all steps of the procedure to learn the information about each step. The scene for the presentation contains a single procedure. The procedure is composed of procedure steps. One step can be composed of several operations. One operation can have multiple hand objects and arrow objects, depending on the number of users who participate in the procedure and the number of required operations. The scene contains two virtual hand objects for each user participating in the procedure and they are arbitrarily separately configurable. The hand objects can be configured to use the left hand, right hand, or both hands. Both hands can be rotated and each finger part can be rotated to mimic the real-world pose of the hand, as shown in Figure 1. In this example, two operators participate in the procedure (*Operator 1* -

green virtual hand objects, *Operator 2* - blue virtual hand objects). Both hands of *Operator 1* are rotated upwards, enabling the operator to push an object forward. The left hand of *Operator 2* has the index finger pointing forward, enabling the operator to push a button, whereas the right hand is rotated towards the left with slightly bent fingers, enabling the operator to lift an object by the handle from the left side. This example shows that different operators can perform entirely different operations within the same procedure step. Moreover, a single operator can use different hand gestures to do two different things in parallel, mimicking the necessary operations that need to be performed in real life.

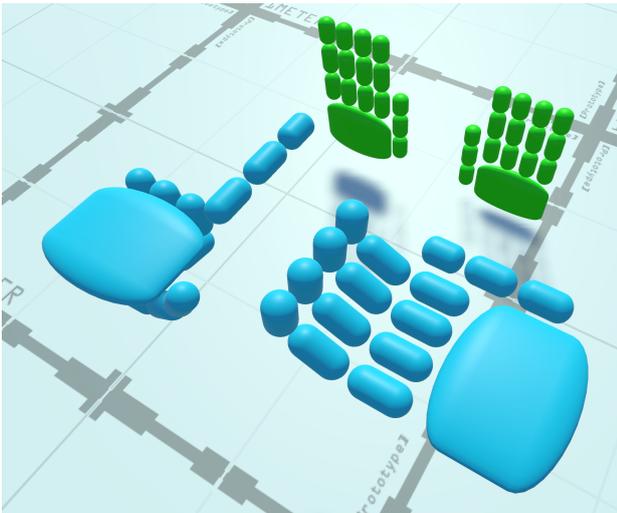


Figure 1: Proposed types of two-handed gestures for multiple operators in the virtual environment

The arrow objects of the presentation scene can contain multiple pieces of information. The different types of arrows are shown in Figure 2. The shape of each arrow shows the path of the required operation (e.g. the green arrow follows a straight path, then turns towards the left, and then follows a straight path again), the tip of the arrow shows the direction of the operation (e.g. the red arrow rotates upwards and then downwards in a clockwise manner), whereas the color of the arrow shows the operation group. The operation group is used to differentiate steps that require multiple simultaneous operations performed by multiple operators at the same time. If multiple operators participate in a single operation step, a single operator is designated a color and all objects that require the assistance of that operator are marked in the designated color. The body of the arrow can also have different configurations along its path. The normal body (the green arrow in Figure 2) is used to show the path of a moving object linked to the starting point of the arrow. A dashed body with animated moving dashes (the blue arrow in Figure 2) is used to show the speed of the operation in addition to its path. A twisted arrow body (the orange arrow in Figure 2) is used to show an operation where pulling and twisting at

the same time is required. A circular arrow body (the red arrow in Figure 2) is used to show a rotational operation. If an operation has a circular motion larger than 360 degrees, multiple arrow objects are used for each full circle and a leftover circle if the last circle is not complete. Some operations can also contain information about the operation result, depicted by using color changes or position changes of other objects after the operation has been performed.



Figure 2: Proposed types of arrows in the virtual environment (red - circular, green - normal, blue - dashed, orange - twist and pull)

3.2 The procedure quiz mode

After the user learns all the steps of the procedure, they can switch to the procedure quiz mode. The quiz mode contains the same number of steps as the presentation mode. Each step contains all objects related to the step from the presentation part (i.e. the correct set of operations) and additional objects that contain incorrect operations. Each question of the quiz is related to a single procedure step where the user is required to choose the right answer by using multiple parameters (the path, direction of the operation, and the operation group, as well as the speed, circular motions, or the operation result if necessary). To answer the question correctly, the user must choose the correct locations where the operations of the given procedure step will be performed, the correct operation types, the correct operators and simultaneous operations, as well as the correct directions and gestures. Throughout the quiz, the user can cycle through each location in the virtual scene. An operation is shown at each location and the user can change its parameters in the desired way or delete the operation so that the location has no operations. It is possible to cycle through all hand and arrow objects of the operation of a single location. When an arrow object or hand object is selected, the color can also be changed in order to choose the correct operators and simultaneous operations. The gestures of the virtual hands can be changed to pick their correct positioning. Multiple dimensions contribute to the difficulty of each question. After each step, the user is informed of whether their answer is correct or incorrect. Only visual ways of describing the outcome are used, as shown in Figure 3, where the user is informed of answering the question wrong by using the X mark colored in red

and shown above their answer on the product. At the end of the quiz, the user is presented with the overall number of incorrect answers and whether they passed the quiz or not.

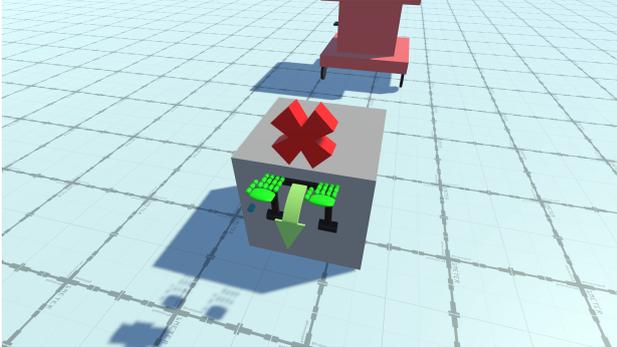


Figure 3: Visualization of the wrong answer in the quiz mode

4 Results

In order to demonstrate the proposed approach, a virtual scene was created by using the *Unity real-time development platform* [14]. The *Procedural indicators* Unity Asset Store plugin [3] was used for creating the 3D arrow models that allow for dynamic parameter modification required for the previously described operation changes. The quiz, all manipulated objects, and the sequence of operation steps were assembled in Unity Editor without importing any data from external sources in the runtime build. The application contains the question templates, operation steps, and the programming logic of the quiz. The operation of the application and the results of a conducted user study are explained in the following paragraphs in detail.

4.1 The procedure presentation mode

The user is first shown the presentation of the procedure that is visualized on the virtual scene in Figure 4. It is visible that the procedure contains four different objects, indicating that the procedure for their usage is very complex. This was intentionally done so that all the different capabilities of the proposed approach can be demonstrated. However, it is important to note that most consumer products would require a much lower level of difficulty, and the procedure from the created use case is more fitting for an industrial or experimental setup. The user can cycle through all of the procedure steps and view the correct operations and all the relevant information about every operation. This process can be repeated until the user successfully learns all operation steps and is satisfied with their level of knowledge.

All steps of the operation are shown in Figure 5 and are described as follows:

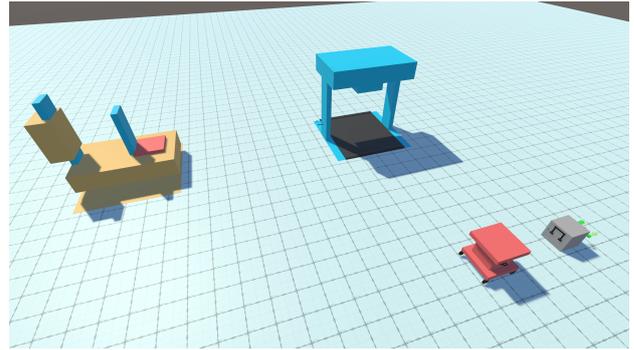
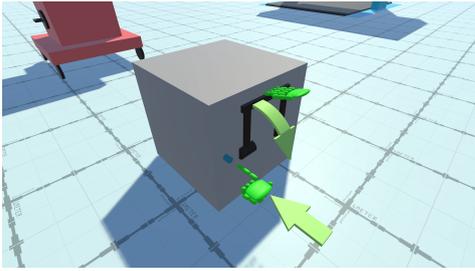


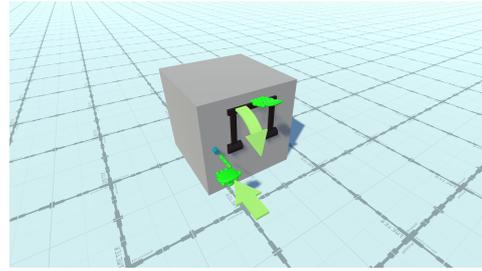
Figure 4: The virtual environment containing the 3D model of the example product

- **Step 1:** Push the button next to the handle and pull the handle down all the way.
- **Step 2:** Do the same operations as during Step 1 on the other side of the box.
- **Step 3:** Two persons need to grab the box by the handles and lift it onto the cart.
- **Step 4:** Pull and twist the pin on the cart so that the wheels unlock.
- **Step 5:** Bring the cart to the scan area.
- **Step 6:** Slowly turn the crank for two full circles in a clockwise manner, until the cart reaches the scan finish area.
- **Step 7:** Bring the cart to the loading area.
- **Step 8:** Lift the box onto the device.
- **Step 9:** Turn the range selector knob full circle in a clockwise manner.
- **Step 10:** Push the button so that the red light turns to green.

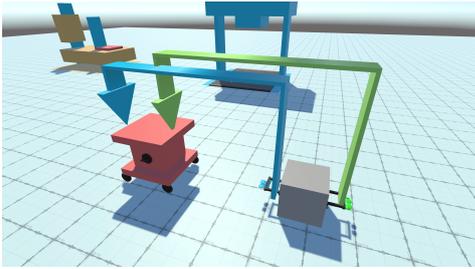
Step 1 (Figure 5a) demonstrates an action composed of two simultaneous operations because the handle can be moved only while the button is pushed down. Steps 3 (Figure 5c) and 8 (Figure 5h) demonstrate actions that are performed by two operators. Step 4 (Figure 5d) demonstrates the twist and pull operation. Steps 5 (Figure 5e) and 7 (Figure 5g) demonstrate different movement operations. Step 6 (Figure 5f) demonstrates the operation speed and circular operations. Steps 9 (Figure 5i) and 10 (Figure 5j) demonstrate operations on a smaller scale. Step 10 also introduces an indicator for the color change that visualizes the result of the operation after it is successfully finished.



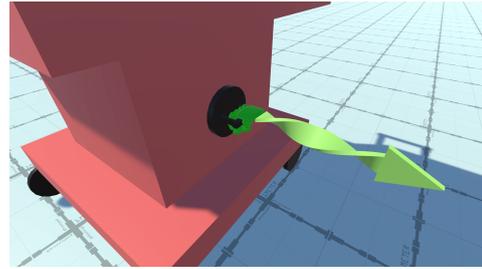
(a) Step 1



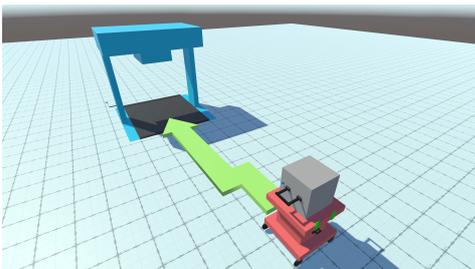
(b) Step 2



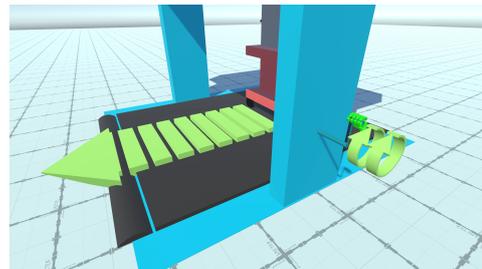
(c) Step 3



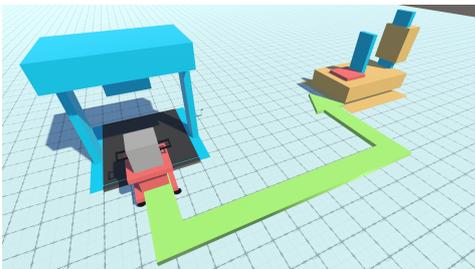
(d) Step 4



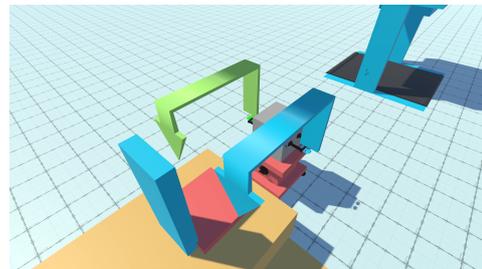
(e) Step 5



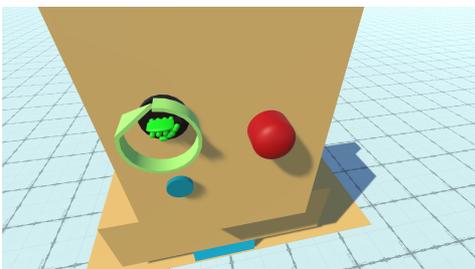
(f) Step 6



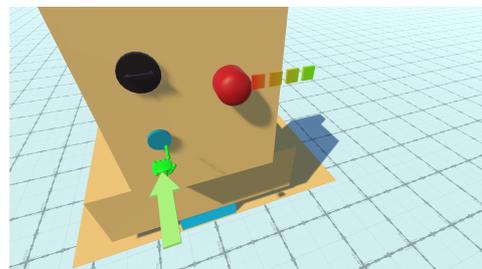
(g) Step 7



(h) Step 8



(i) Step 9



(j) Step 10

Figure 5: Visualization of all steps for operating an example procedure

4.2 The procedure quiz mode

The quiz mode of the virtual scene contains the correct answer, as well as misleading information to test the certainty of the user that the procedure they chose is correct. Each step contains several incorrect locations and operations, and the user must also set the proper groups and directions. The initial setup of the directions and groups is randomized. Each answer also contains different hand positions in the operation, to ensure knowledge of the proper operation type and the correct hand gesture required to correctly perform the operation. The difficulty of the test can be configured by lowering or increasing the number of incorrect locations, incorrect operations, and their similarity to the correct answer. Several possible scenarios that might confuse the user are shown in Figure 6. To ensure the proper understanding of the order of the steps, information from future steps is included as the answers to a given step. For example, all potentially correct and incorrect answers for step 4 are included as answers for step 1 as well (Scenario 1 on Figure 6a). This is used to test the user if they are certain that they should unlock the cart first, or put the box on the cart instead. Loading the box on the cart that has unlocked wheels is a potentially dangerous operation and it is important to teach the user the proper order of the operations. In step 1, the user is also provided with the locations of the two handles and one button. The user must choose only one handle linked to the same button for that handle and a button operation linked to the opening of the handle, as well as the proper directions of the operations and the proper operation group. Step 2 contains incorrect answers from step 3 that include only a single operator with the open handle (Scenario 2 on Figure 6b). This might mislead the user that the box can be lifted without a second operator, which is not possible. Movement operations in steps 5 and 7 contain answers with wrong paths. Step 6 contains answers with the wrong operation speeds of different movements of the cart during the crank-turning operation. One of the variants also shows the user turning the crank once instead of two times and in the wrong direction (counter-clockwise instead of clockwise), as shown in Scenario 3 in Figure 6c.

4.3 User evaluation

A user survey was conducted by using Lyssna [11] to evaluate the proposed approach. The survey was completed by a total of 15 users from different countries around the world with different characteristics (53.33% male and 46.67% female; 20% high school graduates, 46.67% college graduates, and 33.33% postgraduates; 26.67% intermediate and 73.33% advanced computer users; 20% aged 20-24, 20% aged 25-29, 26.67% aged 30-34, 20% aged 45-49, 6.67% aged 50-54 and 6.67% aged 60-64). The users were presented with the image of a single step of the virtual procedure manual and the image of the textual description of the step, after which they chose one or

multiple statements that they agreed with. The results of the survey are summarized in Table 1. A total of 46.67% users chose the virtual manual image as their preferred design, with the maximum age group of 45-49 years. The results indicate that a significant number of users do not read product manuals and that younger users are more open to the usage of virtual product manuals than older users, who rarely chose the virtual manual as their preferred one and agreed with the proposed statements.

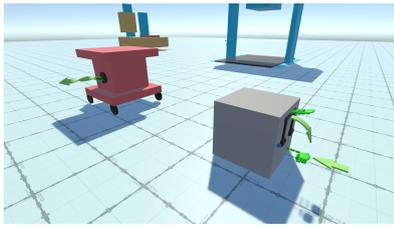
Statement	Agrees	Age group	Education level
When I buy a product, I usually read and use the product manual supplied with it.	9	22.22% (20-24)	11.11% (High school) 44.44% (College) 44.44% (Postgraduate)
		11.11% (25-29)	
		33.33% (30-34)	
		11.11% (45-49)	
		11.11% (50-54)	
11.11% (60-64)			
I would like to use the virtual manual that was shown on the image to learn how to operate the device.	6	50% (20-24)	16.67% (High school)
		33.33% (25-29)	66.66% (College)
		16.67% (30-34)	16.67% (Postgraduate)
The visual description of the procedure by using virtual arrows is simple to understand.	6	50% (20-24)	16.67% (High school)
		33.33% (25-29)	50% (College)
		16.67% (45-49)	33.33% (Postgraduate)
The usage of virtual arrows and hands makes it easier to perceive the required action for handling the device.	6	50% (20-24)	33.33% (High school)
		16.67% (25-29)	50% (College)
		33.33% (45-49)	16.67% (Postgraduate)
It is easier to understand the visual than the textual description of the operation.	3	66.67% (20-24)	33.33% (High school)
		33.33% (25-29)	33.33% (College)
			33.33% (Postgraduate)

Table 1: The results of the preference test of the user evaluation survey

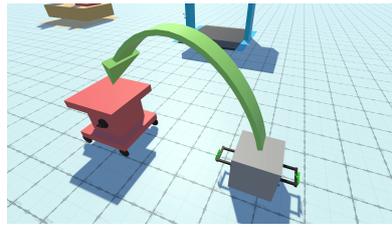
An example quiz question was shown to the users to evaluate the procedure quiz mode, depicting a step of the procedure and what the user needs to choose to perform the procedure correctly. The results are summarized in Table 2. The achieved results indicate that the maximum age group that was familiar with the usage of AR or VR technologies is 30-34. A high number of users would be willing to undertake the quiz, but they did not feel that they possessed a high enough level of digital skills to do it. This is contrary to the perceived level of computer skills that the users selected at the beginning of the survey, which was advanced for a total of 86.67% users.

5 Conclusion

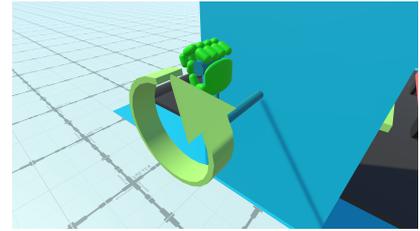
In this paper, we proposed an approach in a virtual environment that can be used in product manuals to teach users about the handling of different products or procedures. Afterward, the user's knowledge about the presented procedure steps can also be tested by using a virtual quiz. The usage of virtual arrows and hand objects makes it possible to show a large scope of potential operations including information that is hard to understand or memorize textually, which makes this general approach applicable to many different types of procedures. The usage of our approach also makes it possible to show all steps of a procedure without using textual information at all. The created quiz has configurable difficulty levels by using different parameter values of the virtual arrows and hand objects. In this way, a



(a) Scenario 1



(b) Scenario 2



(c) Scenario 3

Figure 6: Visualization of different scenarios containing incorrect information during the quiz mode

Statement	Agrees	Age group	Education level
I have previous experience with the usage of virtual reality (VR) or augmented reality (AR) technologies.	5	20% (20-24), 40% (25-29) 40% (30-34)	60% (College) 40% (Postgraduate)
I would be able to undertake this virtual quiz because I have enough digital skills.	6	50% (20-24), 16.67% (25-29) 16.67% (30-34), 16.66% (45-49)	33.33% (High school) 50% (College) 16.67% (Postgraduate)
I would be willing to undertake this virtual quiz to check my level of knowledge.	8	12.5% (20-24), 25% (25-29) 25% (30-34), 12.5% (45-49) 12.5% (50-54), 12.5% (60-64)	62.5% (College) 37.5% (Postgraduate)
The virtual quiz questions are straightforward and understandable.	4	75% (20-24) 25% (30-34)	25% (High school) 75% (College)
I believe that this quiz would help me memorize the correct operation for handling the device.	6	33.33% (20-24), 33.33% (25-29) 33.34% (30-34)	16.67% (High school) 33.33% (College) 50% (Postgraduate)
It is more difficult to answer the questions correctly when choosing the correct arrow than by choosing one of the provided textual answers.	4	25% (25-29), 25% (30-34) 25% (45-49), 25% (60-64)	50% (College) 50% (Postgraduate)
I do not agree with any of the above.	1	100% (45-49)	100% (High school)

Table 2: The results of the design test of the user evaluation survey

large set of potential answers can be created automatically, without needing to design large textual answers. The time needed to describe the path is faster and more straightforward when using arrow objects than by merely describing the whole path with words. The multidimensional nature of the questions furthermore reduces the need to mention every variant that would otherwise need to be described by text, or by using still images. The starting configuration of each question is randomized and answers for multiple steps are intertwined, which removes the possibility of the user learning the questions mechanically, without understanding the procedure or investing the effort to learn the correct order of procedure steps. A small user survey was conducted and it showed that the virtual manuals should mainly target younger age groups with a higher level of education. The number of users that found the usage of virtual arrows helpful is promising, however it was not at a satisfying level for age groups over 34 and users who did not go to college. Most users considered virtual quizzes as helpful, however they were not confident in their digital skills to undertake them. This indicates that additional training needs to be performed to encourage the users to start using modern technologies to familiarize themselves with the desired products.

Our approach presents only the beginning idea for making virtual product manuals more interactive and educational. VR and AR technologies were not utilized in our

approach to make the virtual environment as simple as possible. The strengths of these technologies can be incorporated to improve the quality of the virtual manual presentation and quiz scenes. Existing virtual manuals can be adjusted to include interactive arrows, with the purpose of improving their quality and the level of understanding of the required operation steps by customers. A bigger user survey could then be conducted, requiring the users to learn the procedure by using the first version of the virtual product manual (that contains textual information about product usage) and the improved version of the virtual product manual (that contains interactive virtual arrows and hand objects). The results of the survey could be used to further improve the proposed approach and possibly integrate the two approaches for achieving the best results and a high level of customer satisfaction.

References

- [1] Shafiqah AlAwadhi, Ahmad Said Nafi AlHabib, Daaeen Murad, F. AlDeei, M. AlHouti, Taha Beyrouthy, and Samer Al-Kork. Virtual reality application for interactive and informative learning. In *2017 2nd International Conference on Bio-engineering for Smart Technologies (BioSMART)*, pages 1–4, Paris, 2017. doi: 10.1109/BIOSMART.2017.8095336.

- [2] Aitor Arrieta, Shuai Wang, Ainhoa Arruabarrena, Urtzi Markiegi, Goiuria Sagardui, and Leire Etxebarria. Multi-objective black-box test case selection for cost-effectively testing simulation models. In *GECCO 2018 - Proceedings of the 2018 Genetic and Evolutionary Computation Conference*, pages 1411–1418, Kyoto, 2018. doi: 10.1145/3205455.3205490.
- [3] Cogobyte. Procedural indicators. <https://assetstore.unity.com/packages/tools/modeling/procedural-indicators-105710>, 2024. Accessed: (30/03/2024).
- [4] Halimoh Dorloh, Kai-Way Li, and Samsiya Khaday. Presenting job instructions using an augmented reality device, a printed manual, and a video display for assembly and disassembly tasks: What are the differences? *Applied Sciences*, 13(4):1–17, 2024. doi: 10.3390/app13042186.
- [5] Francesca Ferrati, John Ahmet Erkoyuncu, and Samuel Court. Developing an augmented reality based training demonstrator for manufacturing cherry pickers. *Procedia CIRP*, 81:803–808, 2019. doi: 10.1016/j.procir.2019.03.203.
- [6] Osman Gök, Pervin Ersoy, and Gülmuş Börühan. The effect of user manual quality on customer satisfaction: The mediating effect of perceived product quality. *Journal of Product and Brand Management*, 28(4):475–488, 2019. doi: 10.1108/JPBM-10-2018-2054.
- [7] Simon Kind, Andreas Geiger, Nora Kießling, Michael Schmitz, and Rainer Stark. Haptic interaction in virtual reality environments for manual assembly validation. *Procedia CIRP*, 91:802–807, 2020. doi: 10.1016/j.procir.2020.02.238.
- [8] Enricoandrea Laviola, Michele Gattullo, and Alessandro Evangelista. Displaying augmented reality manuals in the design phase of the product lifecycle. In *JCM 2022: Advances on Mechanics, Design Engineering and Manufacturing IV*, page 1316–1326, Ischia, 2022. doi: 10.1007/978-3-031-15928-2_115.
- [9] Frieder Loch, Gennadiy Koltun, Victoria Karaseva, Dorothea Pantförder, and Birgit Vogel-Heuser. Model-based training of manual procedures in automated production systems. *Mechatronics*, 55:212–223, 2018. doi: 10.1016/j.mechatronics.2018.05.010.
- [10] Federico De Lorenzis, Filippo Gabriele Praticò, and Fabrizio Lamberti. Hcp-vr: Training first responders through a virtual reality application for hydrogeological risk management. In *Proceedings of the 17th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications - Volume 2: VISIGRAP*, pages 273–280, Torino, 2022. doi: 10.5220/00110078000003124.
- [11] Lyssna. Usability test - virtual manual. <https://app.lyssna.com/do/9b90102e5423/caf4>, 2024. Accessed: (30/03/2024).
- [12] Andre A. Pekerti. Augmentation of information in educational objects: Effectiveness of arrows and pictures as information for actions in instructional objects. *Australasian Journal of Educational Technology*, 29(6):840–869, 2013. doi: 10.14742/ajet.312.
- [13] Duc Truong Pham, Rossi Setchi, and Stefan Dimov. Enhanced product support through intelligent product manuals. *International Journal of Systems Science*, 33(6):433–449, 2002. doi: 10.1080/00207720210133624.
- [14] Unity Technologies. Unity real-time development platform: 3d, 2d, vr and ar engine. <https://unity.com>, 2024. Accessed: (08/02/2024).
- [15] Jennifer Tichon and S. Scott. Virtual reality manual handling induction training: Impact on hazard identification. *Asia Pacific Journal of Contemporary Education and Communication Technology*, 5(1):49–58, 2019. doi: 10.25275/apjcectv5i1edu5.
- [16] Wang-Chin Tsai, Wendy A. Rogers, and Chang-Franw Lee. Older adults’ motivations, patterns, and improvised strategies of using product manuals. *International Journal of Design*, 6(2):55–65, 2012.
- [17] Zhengjie Xue, Jun Yang, Ruchen Chen, Qiang He, Qixiu Li, and Xuesong Mei. Ar-assisted guidance for assembly and maintenance of avionics equipment. *Applied Sciences*, 14(3):1–23, 2024. doi: 10.3390/app14031137.
- [18] Liang Zhang, Anwen Hu, Jing Zhang, Shuo Hu, and Qin Jin. Mpmqa: Multimodal question answering on product manuals. In *The Thirty-Seventh AAAI Conference on Artificial Intelligence (AAAI-23)*, pages 13958–13966, Washington DC, 2023. doi: 10.1609/aaai.v37i11.26634.