Authoring-by-Doing: Animating Work Instructions for Industrial Virtual Reality Learning Environments

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ABSTRACT

With the rise of Virtual Reality, gaming is about to reach a new level of realism. The industry sector has recognized the technology's potential too, especially for learning and training of assembly procedures and maintenance tasks. Although gaming and manufacturing industry seem to have different requirements at the first sight, both worlds can benefit from each other. One of the most cumbersome tasks when creating a VR application is the authoring of content, more specific the animation of characters and interactable objects. This paper describes the prototype for a Virtual Reality-supported learning and training application and presents a concept to simplify the authoring process of content with additional focus on animating assembly procedures. Our idea is to record actions performed by an expert in the VR environment. Trainees can watch the recorded actions as semi-transparent "ghost" animation and interactively mimic the set of instructions. By this "authoring-by-doing" approach, we hope to accelerate content creation for industrial VR-learning scenarios.

Keywords: Virtual Reality, animation, industrial training, gaming

Index Terms: [Education]: Industrial training; [Electronic design automation and methodology]: Virtual reality

1 INTRODUCTION

Driven by the gaming industry, Virtual Reality (VR) headsets got affordable and accessible for consumers in recent years. But VR technology also holds great potential for applications in industry, such as training purposes. In comparison to standard 3D training applications on screen, the navigation in VR is more intuitive. Users, who are not familiar with gaming or 3D applications in general, have to learn how to navigate in 3D space using mouse and keyboard. This may distract novice users from the actual teaching goals. Movement in VR resembles real-world actions: navigating in the virtual environment is performed by moving one's body. This intuitive approach allows for a faster entry into the training scenario, while keeping the user focused on the learning content.

Education and training applications can also benefit from various features used in games. According to Gee [1], games are effective "learning machines", communicating a lot of factual knowledge to their users within a short period. In addition, games do a great job in teaching the user without being too intrusive. Learning becomes an enjoyable endeavor, different from formal teaching, which is often perceived as laborious and time-consuming. Video games offer various features which could be adapted for education/training. One of them (the "ghost" feature, a common element in racing games) is described in this paper.

Examples for VR training are scenarios teaching assembly tasks [2], maintenance procedures [3] or trainings, which are too dangerous to be conducted in real-life [4].

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A big challenge for VR is the authoring of content. Most companies have 3D data of their machines or products in form of 2D or 3D CAD drawings, but they still have to create animations to visualize working steps and additionally need to program the logic of the training application. This process is time-consuming and needs expert knowledge to be conducted in a credible way.

This paper describes the prototype for a VR-supported learning and training application and presents a concept to simplify the authoring process for VR-content and animation for assembly tasks. The main idea is that an expert user, who is familiar with a certain work procedure, performs actions in the VR environment. These actions are recorded and can be replayed later. Furthermore, the recorded instructions are interactive and a trainee can follow them step-by-step, while the experts recording is displayed as semi-transparent "ghost" animation, similar to the ghost feature mentioned above. By this "authoring-by-doing" approach, we plan to support the creation of industrial VR-learning scenarios and to foster the adaptation of VR technologies for industrial applications in general.

2 VR AUTHORING TOOLS

As mentioned in the last section authoring is a complex and time-consuming task, where expert knowledge in different applications is needed. Especially for VR training in industrial settings, there is a demand for modifiable applications where one can quickly import new CAD models, define interactions and work instructions and start training new employees.

Commercially available solutions for content creation in VR exist, like *Medium*, *Quill* or *Tilt Brush*, targeting primarily artists. They allow users to create animations or draw in 3D space directly but are not focused on creating interactive work instructions needed for industrial training purposes. In gaming industry, game engines, such as Unity, are popular tools for developing complex interactive VR applications. These applications are also widely used in non-gaming contexts. They combine many useful tools for animating and creating interactions in one application, but require a lot of knowledge, especially in programming. Nebeling and Speicher [5] reviewed and classified existing VR authoring tools and characterized the issues with these tools. The authors state that non-technical designers and end-users are facing a lack of tools to quickly and easily prototype and test new VR user experiences. Still, there are tools that enable designing VR scenes without significant programming knowledge, but they largely do not support explicit interaction. In addition, applications in this area (especially with a strong focus on 3D CAD data) are often developed in an ad-hoc fashion and the development does not follow predefined processes or methodologies [6].

Most related projects described in the introduction implement one specific use case to prove the technical feasibility of an idea. These projects are one-time implementations with no demand to be modified or upgraded later on. Very few and especially recent publications exist so far covering the topic of authoring tools for VR. GVT (Generic Virtual Training) [7] is a platform for creating training scenarios, also utilizing an authoring-by-doing concept,

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but does not focus on authoring purely in VR. Our idea is to develop an authoring tool, which is intuitively to use for novice users and makes use of state-of-the-art VR devices.
The following sections describe our previous work in this area and what we propose to counteract the issues mentioned above.

3 Prototype of a VR Learning Environment

The concept presented in this paper is based on a work at University of Applied Sciences Upper Austria called "VRSmart". This VR application for HTC Vive headsets was developed in Unity and provides tools to visualize, manipulate and interact with complex industry CAD data in VR (see [8] for a detailed description). Our goal was to develop a tool that allows users to quickly review 3D models to get an idea of the design and the underlying construction hierarchy and, in the long run, to use these features for design review and training of new employees. An evaluation in a real-world industry setting showed that the tool supports the communication process between VR and non-VR users sharing the same space. Moreover, VR allowed users to find more predefined flaws in a 3D CAD model than in the CAD software on screen [9]. In a next step we decided to take the prototype to the next level and adapt it for a specific industrial learning use case.
The current version for learning in VR supports the following interactions: looking and grabbing objects according to their construction hierarchy, a virtual cutting tool to see a sectional view of the assembly and a guided assembly procedure. In the guided assembly mode, the user moves parts from one position to another, supported by highlighting effects and instructional texts (see Fig. 1). The system visually tells the user which component to take and where to place it. From a technical point of view, each animation and work instruction was defined in the program code in Unity. This prototype worked for one specific use case (showing one predefined 3D model) and our partner company started using is for training new employees. Unfortunately, it was never used on a broader range for other use cases displaying different 3D models. Manufacturing companies usually have a lot of experience with processing 3D data (CAD), but they often lack of expertise in the areas of animation and game design. Especially dealing with modern game engines is a challenge for companies without expertise in programming. Therefore, the adaptation or extension of an existing VR application is one core challenge for VR in manufacturing industry.

Figure 1: Guided assembly in the current prototype. The user grabs a component and places it at the highlighted position.

To counteract this issue, we started to design an assembly authoring tool for step-by-step instructions (including animations and instructional texts) in Unity. This tool (depicted in Fig. 2) allows non-expert users to compose a set of actions visually, without the need to know about programming or keyframe animation. Start and end position for the animation of a 3D object are defined in a user interface and can be simply modified at a later point. This approach accelerated the authoring process for people, who were familiar with working in Unity (and its editor options), but novice users still had problems to use it. Some users selected the wrong parts in the hierarchy view to be animated for the current work step or entered wrong coordinates. This resulted in unexpected animation sequences and frustration among the users.
This solution can be seen as helpful tool for developers to quickly adapt existing learning scenarios, but does not simplify the authoring process for non-expert users.

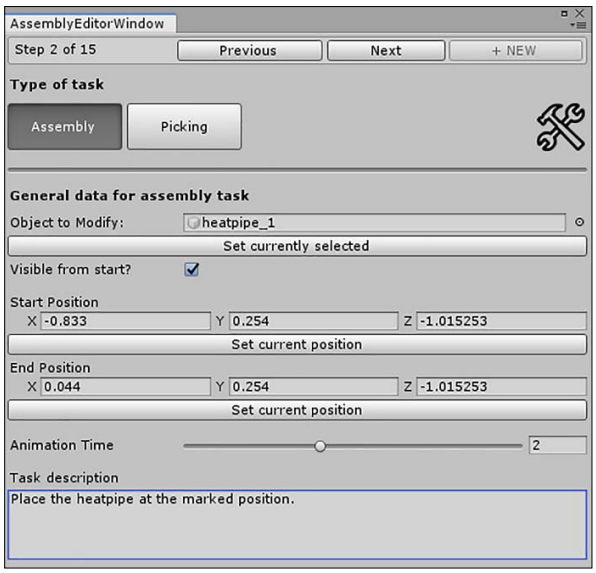

Figure 2: Authoring tool to create assembly steps in Unity. Start and end coordinates for animations are entered manually.

4 A Concept for Authoring-by-Doing

Based on the experiences from the previous section, the concept for an intuitive animation authoring tool for work instructions in VR was created. In a typical work environment, there are long-term employees, who know exactly how an assembly task works and where common mistakes happen. Following the example of an engine assembly (see Fig. 1), those people know each step by heart and usually conduct trainings at the real-world object. They perform the assembly process and novice users watch and repeat each step by their own. Our idea is to apply this process to VR for industrial training.
Games already use a very common approach to guide their players through challenging tasks, called "ghosts". In racing games, for example, players commonly find the option of competing against themselves or others in "Time Trial mode", not just by the final time, but also by racing against a hollow "ghost" recording of a previous run. This might be one's own run, a friend's, or a stranger's downloaded from the web. This ghost (in form of a semi-transparent racing car) either shows another person's run or visualizes a perfect lap, which helps the player to find the ideal line (see Fig. 3 for a visualization of the concept in games).

Figure 3: Concept of a “ghost” in racing games [10]. A semi-transparent car helps to find the “ideal line”.

Following the idea of visualizing a “perfect lap”, we have created the concept of authoring-by-doing for industrial VR-applications: An expert user performs actions in the VR environment. This action is recorded and displayed as semi-transparent “ghost” animation for novice users. In detail, the procedure works as follows:

- An expert user starts the VR application, loads a specific 3D model (for example an engine)
- The expert presses a virtual record button and starts the assembly/disassembly process while commenting the current step by voice
- For each action, an algorithm records the hands’ (meaning the controllers’) and parts’ positions at predefined intervals and saves the audio recordings.
- After each work step, the worker presses a button and continues with the next step
- After the last working step the user stops the recording

Novice users can then replay each step and see the expert’s actions as semi-transparent ghost animation working on the virtual 3D model. Of course, the impact of displaying the ghost (in comparison to simply highlighting, for example the target position of assembly parts) on the trainee’s perception and learning process must be evaluated. Figure 4 shows a first implementation of the concept: The virtual hand visualizes the current task and the novice user imitates the action while listening to the expert’s audio comments. We think there is no need to perform a full body tracking of the expert user, since only controller positions are needed to communicate the core information for manual assembly tasks. If the assembly process includes complex tasks with specific hand movements (such as carefully turning a valve in a predefined direction), the visualization of the controller may not be sufficient. In this case, the expert can use specific hardware to integrate hand and finger tracking (e.g. *Leap Motion* or *ManusVR*).

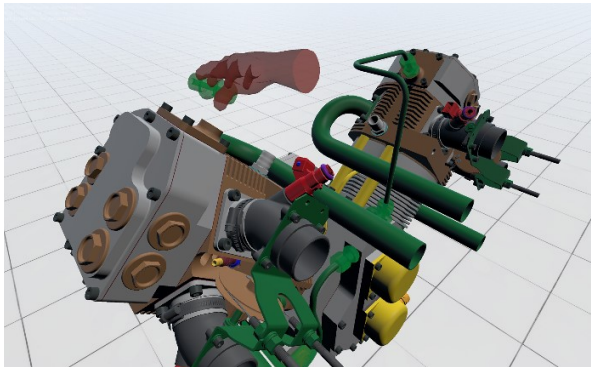

Figure 4: A semi-transparent hand (“ghost”) visualizes the tasks, which have been performed by the expert user beforehand.

By this approach, experienced and novice users have the possibility to store knowledge intuitively, without the need to deal with the underlying software (Unity in this case), keyframe animations or programming code. Taking this idea one step further, recordings of working procedures can be shared globally among remote teams supporting various use cases. The idea is depicted in Fig. 5. All instructions are stored in a cloud. Clients can access specific instructions and follow them locally.

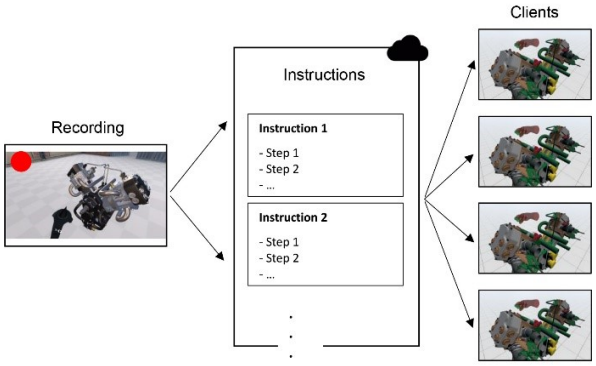

Figure 5: Conceptual overview of sharing recordings among remote teams.

For this concept, we see potential in the following industrial areas:

- Training scenarios: to communicate knowledge recorded by experienced workers (the “perfect run” in gaming analogy)
- Process planning: to verify assembly procedures among remote teams
- Design reviews: to record and share questionable situations in product design
- Maintenance: to store instructions for very common or particularly difficult situations

5 Discussion and Next Steps

In a next step, the described concept will be implemented and integrated in the current prototype. We plan to conduct an evaluation in an industrial setting to compare the current approach using a visual interface to define working steps and the authoring-by-doing approach for guided assemblies. In detail, we want to evaluate, if the animations in combination with audio comments are sufficient to communicate expert knowledge on assembly procedures and if the users understand how to use the tool. Furthermore, we want to investigate, how expert recordings can be stored and shared in a lightweight format. This is the prerequisite to distribute them among remote teams.

The topic of authoring in VR is still underrepresented in scientific research. This paper takes one step to fill the research gap and presents a concept to design the authoring process for VR (with focus on animation) as intuitive and easy to learn as possible. This way, we hope that the technology will be used on a broad basis in industry in the near future.

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