Augmented reality in a serious game for manual assembly processes

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Abstract

This paper presents results from a study in which Augmented Reality (AR) technology has been employed in a serious game for teaching the assembly of a car power generator. Most used car power generators can be remanufactured in order to save material and cost. This is usually done manually and requires a mechanic who knows the different steps of disassembly, cleaning, replacement and re-assembly of the generators components. A serious game has been developed that teaches an apprentice mechanic of which components a car power generator consists and how these components have to be assembled. The game has been implemented as an application for smartphones running the Android operation system. The game employs augmented reality technology in order to let the user interactively experience the spatial arrangement of components and to support the user in validating his learning success.

Keywords: Augmented reality, serious game, training, assembly process.

1 Motivation and Scenario

The education of apprentice mechanics in Germany is carried out following a dual educational approach comprising traditional school classes and practical work in a handicraft business. The use of educational software is uncommon in both theoretical and practical education.

Technological advances in hardware devices (e.g. smartphones and touchscreens) and user interfaces (e.g. AR and touchscreen interaction) allow for the development of new and more interactive educational software that enables innovative ways of learning. Modern educational software could support the existing educational system and possibly improve learning motivation and efficiency.

In this study, the focus is on teaching apprentice car mechanics the assembly process of a car power generator. This process is usually done manually and requires knowledge of all the generator's components and the different steps in which these components have to be put together. Additionally, spatial thinking is required in order to imagine and understand the spatial arrangement of the components. In this study, thus learning software should teach its user specific knowledge (part lists and process steps) and let the user train specific abilities (spatial thinking).

2 State of the Art

The field of learning software is developing quickly. Current approaches for learning software are called eLearning, educational software or serious games [1, 7, 8]. Serious games introduce a new way of motivating people to learn which makes them stand out compared to other approaches for learning software [2]. A serious game lets the user learn something useful while playing and having fun [3]. As many people don't consider learning to be funny, this is a very interesting approach for motivating these people [4, 5, 6]. Interesting serious games for teaching topics related to mechanical engineering comprise Gatscar[1] or Monkey Wrench Conspiracy[2]. All serious games in this field are intended for the use on stationary computers [5].

AR technology has been employed in a wide range of computer games, mostly running on smartphones. There are also serious games that employ AR technology such as Mad City Mistery or Environmental Detectives but they all address topics that are not all related to the scenario presented here.

3 Game Concept and Design

In this study, a serious game called Skillmaster has been developed following a methodology that ensures clear relations between learning goals, gaming aspects (storyline and game elements) and technical aspects (arrangement of views in the graphical user interface). The resulting model is presented in the following figure:

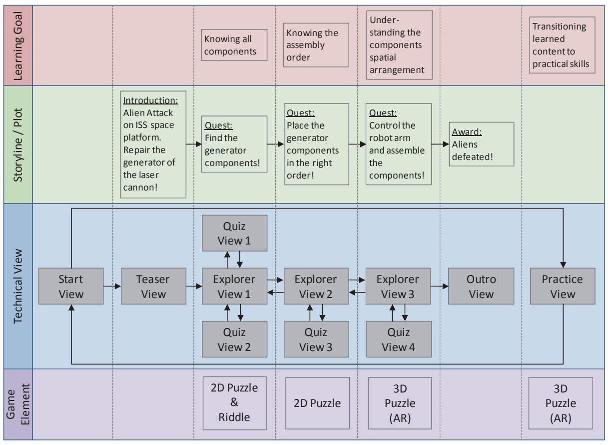

Figure 1. Skillmaster game model

The game's first three learning goals are to consecutively teach its user which components one specific exemplary car generator consists of, in which order they have to be assembled and how they have to be arranged in a 3-dimensional space so that they fit together. Additionally, the user shall be supported in transferring the acquired knowledge and theoretical skills into practice and assemble a power generator in the real world. The storyline, the gaming elements and the graphical user interface have all been designed according to these four main goals.

The game has been designed as a point-and-click adventure in which the user plays the role of an astronaut on the international ISS space platform that is under alien attack. In order to defend

[1] http://www.gatscar-game.com/home.html
[2] http://www.games2train.com/site/html/tutor.html

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the platform, the player has to assemble a broken generator and use it for powering a laser-cannon. The story is supposed to be easy and is not meant to be taken serious. In order to achieve his goals, the player has to advance from room to room in the space platform. Succeeding in mini games opens up new rooms for the player. Each mini game shall convey knowledge or skills that are required for succeeding in the subsequent ones.

Figure 2. Skillmaster game scene: starting room with various interaction possibilities

Figure 3. Skillmaster game scene: interactive drag'n'drop-puzzle

AR technology has been employed for letting the user experience spatial aspects and for supporting the transition of theoretical into practical skills. In the first case (see quest 3 in the figure) the user shall build a better understanding of how the components have to be arranged relative to each other so that they fit together. By moving the smartphone in his hand, the user can move the virtual components accordingly. Starting with the first two components he can arrange one of the two components until both components fit together (i.e. orientation and position are correct). This results in a first partial assembly. Subsequently, the user can arrange the third required component relatively to the existing partial assembly and join both. In the following steps, the user adds one component after another until the virtual car power generator is fully assembled.

The AR-based interaction with the smartphone (using its accelerometer sensor) enables a very intuitive interaction with the virtual components as the user moves his hand the same way he would move it with the real components in his hand. In this case, AR real-life markers are used for allowing the user to interact with virtual objects in a different way. As the users focus is still on virtual objects instead of real objects this should be considered an augmented virtuality approach. Hence, AR technology is not used for augmenting reality in this case but because it enables innovative interaction with virtual objects. This is a phenomenon seen in many other current AR games and whilst it makes sense, it is not in line with the main concept of augmented reality.

In the additional element for supporting the user in transferring his theoretical skills into practice, AR technology plays a conceptually different role: in this case, the user focuses on real objects and the virtual objects shall only support him in achieving a real life goal, i.e. the assembly of a car power generator in practice. In order to do so, the user must have all required components in place and assemble them one by one. The smartphone application shows the user how he shall position the current state of the partial assembly and the component that has to be added next. Once, the user has put both elements together, the application recognizes it and visualizes the same information for the next component.

Figure 4. Augmented Reality mode: part view

Figure 5. Augmented Reality mode: assembly view

This element of the game is not intended for teaching the user new knowledge or skills but for closing the gap between the virtually acquired knowledge and theoretical skills on the one hand side and their practical application on the other hand. As the story of the game progresses the user experiences a switch from purely virtual elements in the first two quests (see figure), over the third quest (applying augmented virtuality, as mentioned before), and finally reaches augmented reality in the final step of the game. At the same time the user transitions from a state of playing into a state of doing something 'serious'. And thus, AR technology allows the game to become 'serious'.

4 Implementation

The game has been implemented as an application for smartphones running the Android operation system (version 2.2). A Dell Streak smartphone has been used for testing and evaluating the application. The development with the Android SDK[3] for Eclipse was supported by the Qualcomm AR (QCAR) SDK v.0.10.0[4] and the Android game engine v. 1.1.1[5] for smartphone games. The game engine allows for designing views in the graphical user interface that lead the user through the storyline and for managing the possible transitions between these views. QCAR allows for AR marker recognition and painting 3D objects relative to recognized AR markers.

In the first application of AR technology, when virtual components have to be properly positioned towards each other, one of the two parts that have to be assembled is aligned relative to an AR marker. The other object is aligned relative to the smartphones orientation.

In the second application, when the user shall assemble real components, the user has to place the partial assemblies on an AR marker in each step. The QCAR has been configured to recognize the partial assembly laying on the AR marker and in which assembly stage it currently is. For every step of the assembly process, there is a different pattern; the computer vision algorithm is searching for.

5 Evaluation

The game has been evaluated by five colleagues of the authors and was exhibited at the International Conference MRO - Maintenance, Repair and Overhaul[6]. A statistically valid study has not yet been conducted. The evaluation focused on the usability of the application and the difficulty of the gaming aspects. It has not been evaluated whether the game could effectively convey the intended knowledge or skills to its users.

The evaluation revealed a few problems regarding finger tip interaction with the touchscreen that could be fixed easily. The recognition of partial assemblies that are positioned on an underlying AR marker proved to be more reliable than expected and also looking at a partial assembly from only one side was sufficient for all observed cases (assembly stages). The balancing of game difficulty proved to be a challenge as some game elements were too easy and others were too hard. Not all of these issues have been fixed up to this date.

Overall, the game was well received and the reviewers wanted to try out playing the game without being asked for it. Stimulating this kind of intrinsic motivation is what the game is aiming at and thus which has been achieved successfully.

6 Outlook

During the development of the game, the authors have developed several ideas and concepts for extending the application's functionality for assisting the user in real work practice. While the existing application is a learning game, it could be followed and integrated with an assistance system for car mechanics. The combination of smartphones (as mobile devices) and AR technology allows for supporting mechanics with relevant information during all kinds of assembly, repair or maintenance activities. In this context the display and exact positioning of 3D models could, for instance, be used to display where a specific component has to be placed. Additionally, animation paths for 3D models could be used in order to visualize the proper way to add a component to an existing assembly.

In order to create such a kind of assistance systems, AR technology for smartphones would have to be improved for a better recognition of 3D markers. The current technology for recognizing pseudo-3D-markers (cubes with 2D faces) will most likely not be sufficient for recognizing the geometrically complex objects that, for instance, can be found in the machine bay of a car.

Instead of applications that are running on smartphones, applications for AR goggles could be used but current solutions of this kind are not sufficiently mobile.

The authors still see a lot of potential in the application of AR technologies for supporting mechanics in learning new processes or performing their daily work and will continue investigating further solutions in this field.

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