Customized Gamification Design in Augmented Reality Training for Manual Assembly Task

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***Abstract*—User engagement in training has always been a concern of organizations, especially in manual assembly and maintenance works. There are many techniques in training design and user experience design to create a captivating environment for the trainees. One of those is to use game mechanisms to stimulate playful experience. On the other hand, Augmented Reality is the technology that can provide significant benefits for manual assembly and maintenance training by providing real hands-on experience, the ability to manipulate 3D objects which are superimposed into the real world in a real-time manner. The combination of these two concepts is believed to optimizing the user's efficiency and experience. While there has been some research into this direction, the work is still nascent and the consideration for individual differences has not yet emerged to the picture. In this paper, we propose a gamified design for manual assembly training that takes different types of the user into account. However, we do not propose a new general design but rather want to experiment with a new approach that considers various user groups.**

Keywords–Gamification; Augmented Reality; Gamified Augmented Reality; Gamified Training; Human-Computer Interaction.

I. Introduction

Augmented Reality (AR) is the technology that can provide significant benefits for manual assembly and maintenance training by providing real hands-on experience on the task. AR allows the user to experience the physical world in combination with virtual content in real-time [1]. Whether it is examining a defect machine part or replacing a component, manual assembly and maintenance work that require the manipulation of objects have always been the key interest in the use of AR application. There are numerous examples both in industrial and academic settings that have provided sufficient evidence for this claim. The first and foremost is the pioneer industrial AR application from Boeing in 1992. The application aims were to assist and increase worker efficiency in the assembling aircraft wire bundles [2]. Another example is the ARVIKA project funded by the German Ministry of Education and Research. The project puts AR technologies in the center for research and developing several head-worn AR-based solutions in various fields like design, production, and maintenance operations [3].

On the other side, user engagement in training has always been a concern of organizations. There are many techniques in training design and user experience design to create a captivating environment for the trainees. One of those is gamification. Gamification is defined as "the use of game design elements in non-game contexts" [4]. Although this is the most common and widely accepted definition amongst academia, the debate over a consensus is still open. In the context of this work, we limit ourselves to the above term from Sebastian Deterding. To make it more clear, gamification is different from another similar context such as "serious games" or "exergames". While the first describes an end product as a game with an ultimate purpose which is higher than pure entertainment; the latter stands for exercise-game, which is self-explaining, in which one does exercise while plays the game.

The combination of these two concepts, AR and gamification, is believed to optimizing the user's efficiency and experience. While has been some research into this direction, the work is still nascent and there is much left to be explored. Most systems provide a single design approach to the user with no customization, which is not inclusive or optimal for the user. The users may have to go through the same procedural training, but their experience does not have to be the same. Therefore, our main contribution in this paper is the gamification design for different user types. However, in this paper, we do not propose a new general design for customized gamification in AR training systems since it would diminish the users and their individual needs. We rather want to experiment with a new approach that considers various user groups. Although our system demonstrates on a computer assembly use case, it could be used as an example for all other manual tasks which share similar characteristics: being procedural, having pre-designed content, requiring the manipulation of physical objects and tools.

The paper is organized as following: motivation is presented in Section II. Section III provides an overview of existing works. Section IV and V respectively describe the application design and gamification design. Section VI concludes the paper with a brief conclusion and future work.

II. Motivation

Apart from fancy promising effectiveness of changing people's behaviors by good motivation and engagement, the use of gamification in industrial production is far from matured or beyond the lab-based trial. Despite all its benefits,

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gamification is predicted to fail to live up to its expectations [5]. Gamification is all about design for people's motivation and engagement. Thus, gamification can be and should be personalized, tailored based on one's preferences for the best results.

However, all the existing works dismiss the role of the individual in designing gamified training. The common practice is a stereotype. It assumes that all users are treated as one group instead of individuals with different characteristics and approaches. For example, when the rewarding mechanism is deliberately used for the wrong users it could lead to "over-justification". "Over-justification" is a term in psychology to describe the situation where a high intrinsic motivated person gets demotivated by extrinsic recognition [6]. Once the user gets used to received rewards, the absence of it potentially may promote negative effects.

Figure 1. Bartle taxonomy of player types [7].

Game academic Richard Bartle proposed a classification of player types named after himself - the Bartle taxonomy [7]. These categories are the Achiever, the Explorer, the Socializer, and the Killer. Although it's tempted to fix a player into a specific category, it's more than one type that ignites the player's motivation. As demonstrated in Figure 1, the Achiever and the Killer types are somewhat similar in their competitive nature while the remained two focus on interacting with the surrounding world and people. It is important to understand the players to meet their needs, instead of stereotypes.

III. Related Works

AR for manual assembly tasks and maintenance training is finding its way into daily practices. It is because of the tremendous benefit of hands-on or on-the-job training experience. AR enables the possibility of manipulating assembly components, which are superimposed into the real world, in a real-time manner altogether with additional 3D instructional information. In designing AR training applications, it is not uncommon to borrow concepts or design guidelines from other well-established disciplines such as education and training design. That is to say, gamification is one of those.

The use of game-like design first was intended to engage and motivate students to learn. Taking an example from the historic role playing AR game "Re-living the Revolution" from Schrier [8]. A player is pre-assigned to a specific historic role and spot, after that, a GPS-enabled handheld device will guide the participants to the real site through a real site map with augmented information about the historic event related to their roles. A completed action results in items about the role and spot. Her results showed that students had developed better skills in problem-solving, collaboration via working together with other students to accomplish the given quest. Reports have been continuously stated the positive and promising results that businesses, and organizations learn from applying gamification.

Despite its fame, gamification is still a new trend in the context of industrial training. The unique characteristic of this field is that the employee's concentration on the task at hand is non-negotiable. Neglecting this requirement may result in injuries, damages to the equipment, and products themselves. One pioneer work on industrial gamification in the particular domain of assembly tasks is the Industrial Playground from Oliver Korn [9]. Korn and his research team transformed a traditional assistive system for the impaired worker at a manual assembly station into a gameful design one. And instead of a stationary monitor, projectors were used to project the design interfaced into users' working surface, which is directly in the users' field of view. The assembly process was animated as a Tetris game. Each brick, which was color-coded from green to red to indicate one's performance, represented for a work step. Basing on this base project, further studies were conducted and indicated promising results [10] [11]. Not only the workers showed openness and acceptance for the new design, but their performance was also improved.

Another work that combines AR and industrial gamification is a manual assembly training, procedural guidance for changing a robot arm batteries, from Nguyen [12]. The design of gamification is represented by a points system, progress bar, and signposting element. Each action that the user has to perform worth's a point while a training step, which consists of one or many actions, is visualized through the progress bar. While the target users of the system are novices, signposting provides an in-situ hint over which components should be targeted. In this experiment, the participants were separated into two groups who underwent an identical training process except one with the gamification design while the other did not. The participants performed the training task with a Head Worn Display (HWD), the Microsoft HoloLens, in a controlled environment to ensure everybody was exposed to (nearly) the same environmental conditions. The results showed a more homogeneous effect in user engagement through the task when the game design is present.

Brauer et al. recently presented an application that combined Gamification and AR to support the warehouse process with order picking [13]. Even though it is not an assembly task, this work is a very rare investigation about isolated individual game design elements' effectiveness. For order picking, the user must navigate through the warehouse in the specifically designed path and follows a fixed sequence of actions. Therefore, to some extent, it shares the nature of procedural work such as assembly. The design elements which are under investigation are leader-board and badge. The participants use also the Microsoft HoloLens to pick up 10 orders in the warehouse. After each picking, the user will receive performance feedback either displaying on a leader-board, receiving a badge, or nothing (no gamification support). Results revealed that the gamification is significantly improved user performance and motivation in opposition to non-gamification design.

IV. Application Design

The proposed training system is a mobile AR application that runs on Android platform. The test application is run on Samsung Galaxy S9 [14], which supports ARCore [15] and allows using the phone's camera for AR applications .

The application is used for training users on how to perform an entire assembly and disassembly of a computer which includes a motherboard, power supply, the Central Processing Unit (CPU), the Random-access Memory (RAM), Hard Disk Drive, Video Card, Optical Drives. The application contains three main modules: Assembly, Disassembly for procedural training, and Component Learning.

A. Procedural Training

The assembly and disassembly training is procedural training in nature. The assembly/disassembly module is a complete step-by-step instruction for AR training. The application could later be used in various areas, both private and business sectors, for example, to support IT specialists in their training and to teach them how to completely assemble and disassemble a computer. There are 47 assembly steps and 32 disassembly steps. There are three main actions throughout the process: removing a component, putting a component in the right position, pushing /pressing a component. At the beginning of the training, short guidance is displayed to show the user the meaning of the symbol:

- The blue hand with index finger pointing out: pushing/pressing on the component.
- The red hand: showcase the direction that the corresponding action should be performed.
- A screw driver/screw: indicating the needed tools.

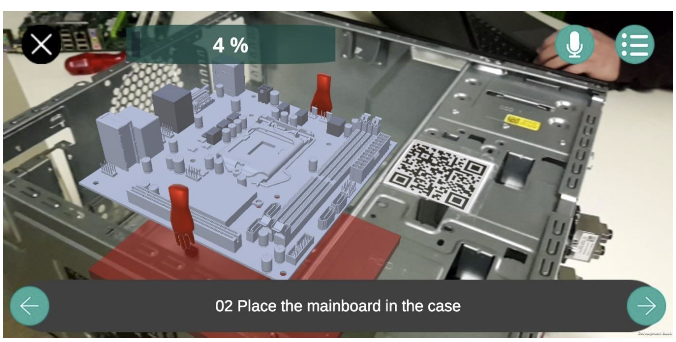

Figure 2. Training step display with multiple instruction components.

A step instruction as in Figure 2 includes five main components: text description of what needs to be done, a CAD model of the assembly components, a 3D model of the required tool, a hologram of the target destination, and the in-situ guidance of the corresponding action.

To navigate directly to a specific step in the assembly or disassembly, one can use the ”Steps Selection” function. This function allows the user to directly start a specific assembly step without having to click through all previous steps. This is useful, for example, when one wants to practice a specific assembly/disassembly step directly.

To simplify the navigation between the screens and between the training steps, voice control is integrated into the system. So there are two possibilities to navigate within the application. On the one hand via the navigation buttons contained in the individual screens, and the other via various specific voice commands, such as ”Exit”. This voice command would take you back to the main menu.

B. Component Learning

The ”Learning” function of this system is particularly interesting for this area. This function offers the user the possibility to get to know the individual hardware components of the computer. The learning module is built using the object recognition function. Whenever a component is placed into the field of view of the mobile camera, a detailed description of the component is displayed. It describes the elements in the detail of what it is and what are the functionalities. A 3D model database of all the computer components was built in advance for extracting the learning content.

V. Proposed Gamification Design

A. Points System

The points system works in such a way that a certain number of points (50, 100, or 200) are awarded per assembly step. The number of points depends on how quickly an assembly step has been carried out. The faster it is carried out, the higher the score. A certain amount of time is given for each assembly step, which is the pre-recorded average time of 5 novice users who are the target users of the system. This recorded time corresponds to the best time (200 points). Whenever the user finishes a step, the corresponding score will be added up to the trophy which reflects the overall performance. For example, if the user performs slower than the best time but faster than twice the best time, 100 points are awarded for the step, anything slower than twice the best time will score 50 points. After each step, the score is animated to the big cup and added to the previous score. The lower progress bar is color-coded to indicate the user performance at each step and the time left to reach the corresponding score. In the upper part of the screen, there is a timer, which shows the currently required time per assembly step (restarted after each step). The second is a trophy, which represents the total number of points and which changes to a silver or gold trophy the higher it is.

B. Badges

Besides, it is possible to preserve unique achievements. These are awards when a certain goal has been achieved. Such a goal can be for example the achievement of a Gold Cup or the completion of a certain number of assembly steps. Once a goal has been reached, the corresponding achievement as in Figure 3 is displayed for two seconds.

C. Leader Board

As soon as the whole assembly or disassembly process is finished and thus the total number of points, as well as the final cup, is defined, they are placed on the high-score screen.

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Figure 3. User achieves different badges when a certain goal has been achieved.

D. Competitive mode vs Non-competitive mode

As discussed in section II and III, we bring the player types into consideration for providing customized user experiences. A user can select either the ”Competitive Mode” or the ”Normal Mode” for his training session depending on his characteristics. By allowing the freedom of choice, the hypothesis is that the user will experience the most suitable gamified design for his dominant characteristic. The application offers a choice between two modes each time the assembly and disassembly instructions are started.

The ”Competitive Mode” (Figure 4) is designed for users who are highly competitive, predominantly Achiever and Killer. In this mode, the user will experience the points system, badges, and also leader board. Regarding the competitive nature of a user, he can set a user name at the beginning of the training in order to compete with others on the leader-board. The training then is designed with time pressure. Each step is pre-set with a time limitation to get either a gold, silver, or bronze trophy as described in the points system section. This will provide a sense of competition with others which suits the player type.

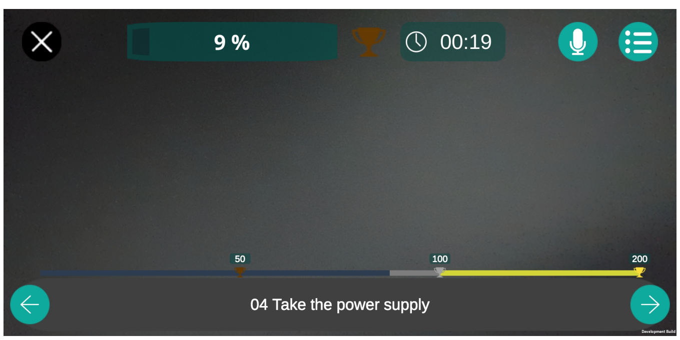

Figure 4. Competitive Mode

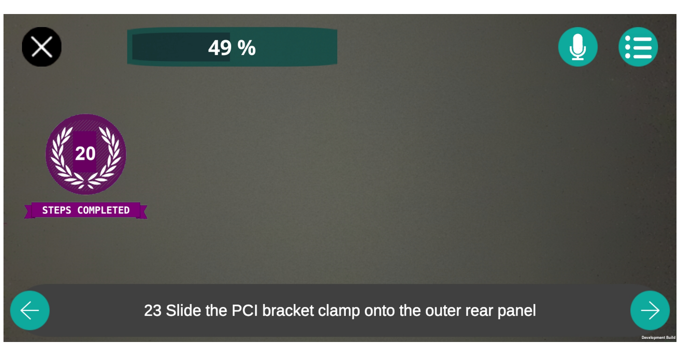

Figure 5. Non-competitive Mode .

In ”Normal Mode” (Figure 5), there are no time limits and therefore no points or leader board. This mode is intended for users who are not looking for competition. The badges are available in this mode also. This allows us to simulate the sense of achievement without pressing users into the competitive mode.

VI. Conclusion and Future Work

In this paper, we addressed the problem of considering individual differences in gamification design for AR manual assembly training. We introduce an approach to gamifying the training process with the integration of player types concept. It provides the ability to select a play mode that allows the training to be modified, visualized to fit one’s predominant nature. The ultimate goal is to embolden motivation and user engagement.

The proposed design approach will be tested in the next step. We will evaluate its effectiveness as well as its impact on the user’s performance. It is interesting to figure out if there is a difference in user experience when the users are left aware and unaware of the choices.

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