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Serious Games and Virtual Simulator for Automotive Manufacturing Education & Training

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Abstract. Manufacturing industry is facing important challenges in terms of sustainability, flexibility, ramp-up and time-to-market shortening. This is pushing RTD towards digital tools and methods to simulate and test production processes beforehand and thus bridging the gaps between manufacturing engineering and production. For example, virtual training offers a huge potential to reduce the time and effort of traditional hardware training and thus leading to shorter production ramp-up time. However, before being deployed in an industrial environment, virtual training systems need to prove their reliability and user acceptance. The purpose of this study was to determine the impact of gaming experience on the learning process of a manufacturing operation using the VIrtual Simulation and TRAining (VISTRA) system, a serious game that simulates manufacturing environments in order to train operators to perform manual tasks. The simulated operations take place at a welding workstation for truck chassis parts, where automation and manual tasks are combined. The case study aims then to evaluate the impact of gaming-experience and the general usability of the VISTRA system. Ten operators participated in the study; each operator completed five different training scenes on three difficulty levels each. Completion time and mistake count were computed by the VISTRA system after completing each training scene. This information was analyzed and compared. Results showed that: (1) users without gaming experience took considerably more time to complete the sequences than users with gaming experience, (2) the same amount of mistakes were made by gamers and by no-gamers, and (3) 50% of the mistakes were made during a particular scene. The study thus found that gaming experience influences positively on training completion time using the VISTRA system. The particularities on the mistake count demonstrated that gaming experience does not influence the understanding of the manufacturing operation. Usability issues found on users' feedback are further discussed in terms of visualization, tools and parts, assisted-learning and ergonomics.

Peer-review under responsibility of organizing committee of the 2015 International Conference on Virtual and Augmented Reality in Education (VARE 2015)

Keywords: Serious Gaming; Virtual Reality; Manufacturing Training; Game Usability

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1. Introduction

Information and Communication Technologies (ICTs) contribution to the research on manufacturing must aim at improving the efficiency, adaptability and sustainability of production systems as well as their better integration within business processes in an increasingly globalized industrial context.

Supporting industry through research projects is very important in order to bring together ICT suppliers and users for experiments that target the broad uptake of ICTs towards a more sustainable, efficient, performant and smarter manufacturing industry. The focus of this research work is on emerging innovative technologies and processes, which need to be customized, tested and validated before being able to compete on the market [1].

One of these innovative technologies is Virtual Reality (VR), since it is a very helpful and valuable tool for the simulation of manufacturing systems. Virtual Manufacturing (VM) can be used in both industrial and academic/ researcher fields allowing the system's behavior to be learnt and tested. VR provides thus a low-cost, secure and fast analysis environment. It also provides benefits, which can be reached with many different system configurations [2]. A VR system is an interactive technology setup (software, hardware, peripheral devices, and other items) that acts as a human-to-computer interface (HCI) and immerses its user in a computer-generated three-dimensional environment. VR is the environment or world that the user experiences, while using such system. Although the term "virtual" implies that this simulated world does not actually exist, the term "reality" refers to the user's experience of the simulated environment as being real [3].

VISTRA is a VM solution that turns the "real world" of assembly operations training environment into a "virtual" environment [4]. A virtual assembly is defined as: "the use of computer tools to make or 'assist with' assembly-related engineering decisions through analysis, predictive models, visualization, and presentation of data without the product realization or support processes" [5]. In assembly operations, VM is mainly used for investigating the assembly processes, the mechanical and physical characteristics of the equipment and tooling, and the interrelation among different parts and factors affecting the performance of the operation based on modeling and simulation tools [6].

When it comes to learning on virtual environments, it is clear that user interfaces must become more intuitive following the requirements of the individual learner and reinforcing the drive towards more personalized learning and greater learner autonomy [7]; this is why user integration and acceptance are key aspects to research about.

Virtual assembly training systems show a high potential to complement physical setups for training of assembly processes in and beyond the automotive industry. The precondition for the breakthrough of virtual training is that it overcomes the problems of former approaches, such as: the extensive authoring effort for setting up virtual environments, the lack of data integration, and the insufficient user integration and acceptance [4] [8]. This paper conducts a test for users' integration depending on their previous exposure to gaming experiences.

2. Materials and Methods

2.1. VISTRA Training Simulator

The VISTRA Training Simulator (VTS) represents an interactive virtual assembly simulation, which is used to train and test manual assembly processes. The VTS provides the actual training functionality to the trainees. As shown on Fig. 1, the VTS communicates internally with the VISTRA Knowledge Platform (VKP) in order to request and restore training content. Planning training sessions and reviewing training results are important tasks of the third and last system component, the VISTRA Knowledge Sharing Centre (VKSC).

The VTS will allow a playful exploration and learning of complex assembly processes in a realistic virtual reproduction. The VTS focus is on the training of procedural knowledge, such as build sequences.

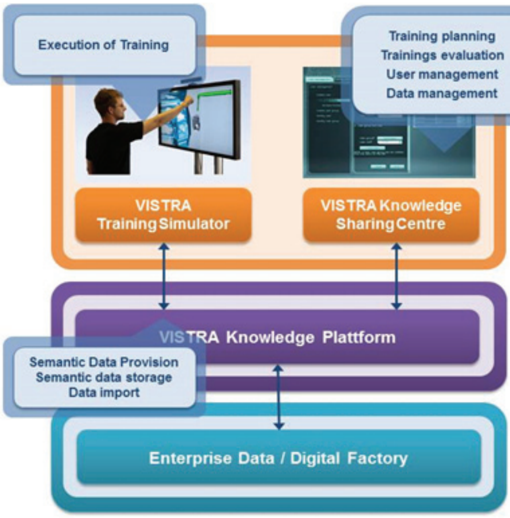

Fig. 1. VISTRA High-Level Architecture

The hardware set-up is designed to allow a natural and more realistic interaction with the virtual objects and the virtual environment/reality. It employs a Microsoft Kinect camera for hand and body tracking and a Nintendo WiiMote controller for the virtual objects manipulation (see Fig. 2). The features provided by the Microsoft Kinect, and its corresponding software development toolkit (SDK), enables the system to capture and track the user's body position and posture within the virtual scene. In combination with a hand-held Nintendo WiiMote controller, the user can directly manipulate virtual objects (e.g. parts and tools) using the corresponding "real-world" actions performed during the assembly process, e.g. rotating and twisting an object. In addition, the hand-held device provides means for triggering "virtual" actions, e.g. button presses, as well as acoustic and haptic feedback through the included actuators [8].

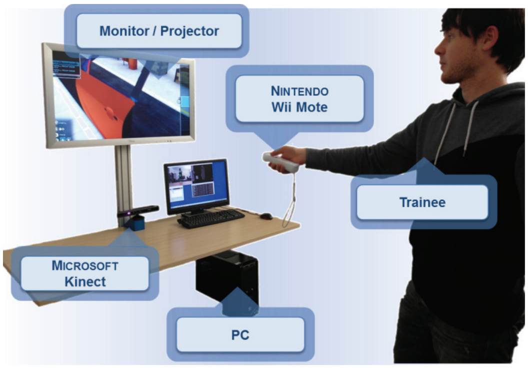

Fig. 2. VISTRA Hardware Set-up

2.2. Virtual Scenes Description

The first scene taught to the operator during the usability evaluation was to load a component on a fixture and to weld a nut to it. The second scene features the manual steps for loading a robotic welding machine. On the third scene, it is showed the component welded in the previous step, and the new components are loaded in a rotary fixture (see Fig. 3) so that the welding can be done manually on the first position. On the fourth and fifth scenes, manual welding is featured for the second and third position of the rotary fixture, respectively.

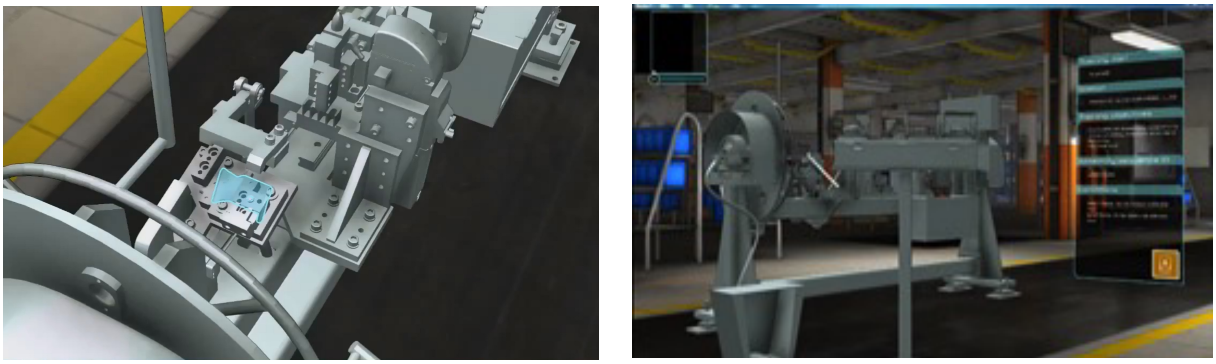

Fig. 3. Manual Welding Virtual Scenes

2.3. VTS Difficulty Levels

On the VTS environment, the operators (users) completed five scenes, once at each difficulty level (easy, medium and expert). Total of steps to be completed were 18 steps.

In the easy mode, parts and tools were presented in sequence to the operator in close-up view while the name of the part or tool was provided as text simultaneously. Pressing the B button on the Nintendo WiiMote controller snaps the part or tool to the target position, which is permanently highlighted. If the operator struggles to position the part or tool for 30 seconds, a prompt appears to ask if the operator wants to choose auto-completion for this step or if the operator wants to keep trying (trying again).

The medium mode works the same way that the easy mode with one difference: The operator has to select the parts and tools from the inventory. This forces the operator to consider in what sequence the assembly steps should take place.

The expert (difficult) mode is like the medium level, but the target position is not highlighted, with the aim of making the operator to remember where to place the part (component) in order to ensure the comprehension and memorization of the assembly sequence. For this particular use case, poka-yokes and previous parts assembled may help the operator to remind the right target position.

2.4. Measurement of Initial Training Time and Performance

In order to evaluate the feasibility of a full deployment with operators (mostly) without experience on gaming platforms, the experiment was conducted contrasting the completion training time and performance of engineering students with and without gaming experience.

The initial training time and performance was based on the completion time of the easy level and the mistakes made at the medium and expert (difficulty) levels.

2.5. Usability Measurements

Five questions were made to the participants, each one regarding a different aspect of the VTS. The experimental criterions were: fidelity to reality, tool handling, contribution to the learning process, assembly sequence understanding, and ergonomics.

2.6. Evaluation Procedure

Fig. 4 presents the evaluation procedure performed during the experiment.

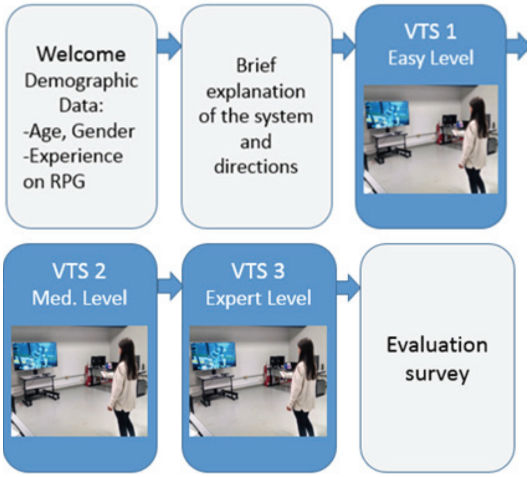

Fig. 4. Evaluation Procedure for the Case Study

The participants of the sample were informed about the aim of the VISTRA system and asked for some general personal data to conduct the experiment. Right after, they were instructed about how to use the system and the differences between difficulty levels. Then they tried/tested the system, three times per scene, once for each difficulty level, and then they took a quick survey to comment about the system. Each participant took about 20 minutes (average) to complete the tasks presented in Fig. 4.

2.7. Study Design

The purpose of this quasi-experimental study is to determine the impact of gaming experience on the learning process of a manufacturing operation (assembly sequence) using the VISTRA system. The study was conducted in a lab environment, and ten random subjects were chosen, having as a grouping variable the previous gaming experience and the completion time and mistake count as dependent variables. The data was collected by the VISTRA system as the participant completed the test, and then put into descriptive statistics graphs in order to compare the results.

Table 1. Pre-Survey for Demographic Data

	Sample	**Gamers**	**No-Gamers**
Age	M =23.2 (SD = 1.48)	M = 23.8 (SD = 1.48)	M = 22.6 (SD = 1.34)
Gender			
- Male	n =5	n = 4	n = 1
- Female	n = 5	n = 1	n = 4
Handedness			
- Right	n = 9	n = 5	n = 4
- Left	n = 1	n = 0	n = 1

3. Results

3.1. Effectiveness

The effectiveness of training is measured based on the time taken to complete the training tasks. Tables 2 and 3 present the data obtained from the easy, medium and expert (difficult) mode levels.

Table 2. Operators' Completion Time on Easy Mode-Level (seconds)

TOTAL		**SCENE 1**		**SCENE 2**		**SCENE 3**		**SCENE 4**		**SCENE 5**	
Gamers	NOT Gamers	Gamers	NOT Gamers	Gamers	NOT Gamers	Gamers	NOT Gamers	Gamers	NOT Gamers	Gamers	NOT Gamers
140	196	22	24	32	57	32	49	23	30	19	22
147	233	22	33	43	60	40	55	28	37	21	23
176	240	26	33	44	62	46	57	31	42	24	25
184	241	26	35	53	78	47	64	34	52	27	30
194	344	28	37	54	100	48	65	37	152	34	31

Table 3. Mistake Count on Medium and Expert Modes-Levels (combined)

TOTAL		**SCENE 1**		**SCENE 2**		**SCENE 3**		**SCENE 4**		**SCENE 5**	
Gamers	NOT Gamers	Gamers	NOT Gamers	Gamers	NOT Gamers	Gamers	NOT Gamers	Gamers	NOT Gamers	Gamers	NOT Gamers
0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	1	0	0	0	0	0
2	2	1	0	0	1	1	0	0	0	0	0
3	4	1	0	1	2	2	3	0	1	0	0

3.2. Usability

In order to complement the system effectiveness' evaluation, the participants were post-survey about the usability aspects (see Section 2.5) of the VTS following the experimental criterions used on previous evaluations, following the VISTRA informed consent and evaluation process [8].

Operators (users) seem to accept/like the VTS, most of the comments stated that the simulation is very close to the "reality" and that learning process is described as comfortable. Nevertheless, feedback comments showed us that the system still requires some adaptations and improvements (see Section 4).

Most positive comments were about the similarity to the "real" process. The operators (users) have seen the video of the real process and they stated that the simulation has a very high similarity. Users also said that the VISTRA technology is well suited to improve the learning process. The most frequent feedback comment was about the parts inventory, the users said that since some parts are alike, the image of the part on the inventory should be showed in an angle that actually could help to tell the differences from one to another. Users also said that the automatic calculated camera position was sometimes uncomfortable, since they had to adjust the perspective of the camera manually.

4. Discussion

At a first glance, the reader can see in Fig. 5 that users without gaming experience took more time to complete the sequences than the users with gaming experience. The reader can also infer that the time-elapsed by users without gaming experience had more dispersion than the ones with experience, maybe because the differences between each one's previous exposure to this kind of tools.

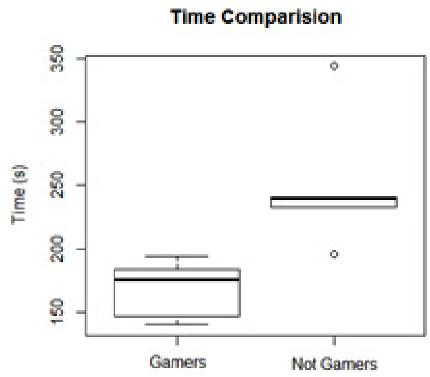

Fig. 5. Boxplot for Total Time on the 5 Scenes

As it can be seen in Fig. 6, the same amount of mistakes was made by gamers than by no-gamers. According to this, it can be supposed that making a mistake depends on the understanding of the sequence and not on previous gaming experience. This is demonstrated in Fig. 7, where it can be noticed that 50% of the mistakes were made on the Scene 3, so it can be concluded that it is the most difficult to understand, and must be reinforced to enhance the learning process.

Fig. 6. Mistakes per Group

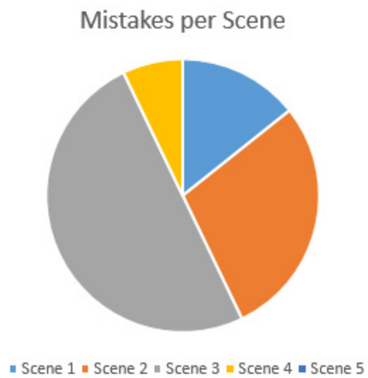

Fig. 7. Mistakes per Scene

The sequences (scenes) were presented to the innovation department of the automotive supplier for which the case study was made for. Thereby practical aspects of the VTS were evaluated and compared to the “real” workstation. According to the company, the VTS is promising for a full pilot study, although first some technical enhancements need to be made:

- Points of view (PoVs) partly varied from the reality. PoVs need to be set according the actual position of the operator at the moment of the operation.
- Parts put in the target position should remain at the ribbon (part inventory) in order to add complexity for choosing parts alike.
- A common mistake on the actual (real) workstation is placing a part upside down or flipped, but this situation wasn’t considered on the simulation, where only translation of parts is possible. More degrees of freedom (DOFs) could be added by using a nun-chuck hand-held device.
- Welding torch operations are successful just by taking the tool to the target position. Continuous movement while holding B-button following the welding path may face the user with an actual (real) representation of the real task.
- At the manual welding workstation, the three positions of the tooling should be in one scene in order to facilitate the comprehension of the tasks and their order.

5. Conclusion

In this paper, authors presented a case study of the VISTRA virtual training system to evaluate the usability and the influence of user’s gaming-experience. Overall, the study shows the high potential and acceptance level for virtual training to be integrated into industries, such as automotive. Furthermore, the findings of this evaluation confirmed that the impact/relevance of the “user’s gaming experience” exists just in terms of completion time of the training. Regarding the learning process, experience on gaming platforms does not seem to change the way the users recall the order of the assembly. This suggests that senior people who have never played video games may not find difficult making their way around virtual training systems, perhaps just their first training sessions would take some extra time. The participants’ comments also make clear that some improvements need to be made, but the general purpose of training was accomplished in a lab environment.

Acknowledgements

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