Combining Virtual and Augmented Reality to Improve the Mechanical Assembly Training Process in Manufacturing

Conference Paper · January 2012

4 authors:

Amaury Peniche
Universidad EAFIT

Christian Andres Diaz
Universidad EAFIT

Gabriel Paramo
Universidad EAFIT

Helmuth Trefftz
Universidad EAFIT

Combining Virtual and Augmented Reality to Improve the Mechanical Assembly Training Process in Manufacturing

AMAURY PENICHE
EAFIT University
Virtual Reality Laboratory
Carrera 49 N 7 Sur - 50, Medellin
COLOMBIA
apeniche@eafit.edu.co

CHRISTIAN DIAZ
EAFIT University
Virtual Reality Laboratory
Carrera 49 N 7 Sur - 50, Medellin
COLOMBIA
cdiazleo@eafit.edu.co

HELMUTH TREFFTZ
EAFIT University
Virtual Reality Laboratory
Carrera 49 N 7 Sur - 50, Medellin
COLOMBIA
htrefftz@eafit.edu.co

GABRIEL PARAMO
EAFIT University
Production Engineering Department
Carrera 49 N 7 Sur - 50, Medellin
COLOMBIA
gparamo@eafit.edu.co

Abstract: Nowadays, the industrial sector and specially manufacturing companies, have a huge challenge trying to train the workforce while maintaining up to date with the technology, machinery and manufacturing techniques involved in the production process. For that reason this sector claims for effective, in time and quality, training methodologies that do not interrupt or interfere with the continuous workflow of the company or its technological evolution.

Virtual reality offers an alternative that has been successfully implemented in other industries. Virtual reality based training systems have numerous advantages over the conventional methodologies, however, for some applications, virtual reality cannot replace the whole training process because it may be incapable of sufficiently transferring the skills to real world. On the contrary, augmented reality operates in a real environment, providing computer-generated aids to the user in order to “enhance” the real world; therefore, augmented reality based training systems may transfer skills in a greater extent compared to virtual reality. However, augmented reality does not provide all the advantages that virtual reality does, as it makes extensive use of resources like traditional methodologies do. This paper proposes a new methodology that combines virtual and augmented reality; a complete and robust process that fits more complex and demanding training needs of manufacturing companies.

Key–Words: Training Process, Training System, Virtual Reality, Augmented Reality, Manufacturing, Mechanical Assembly

1 Introduction

Training is a vital process in the industry, and especially in the manufacturing industry. Regardless of previous experience that new employees may have in previous jobs, it is almost certain that they need some level of training in company-specific tasks or operations. The traditional methodology is the most widely used in industry nowadays, which basically is carried out by an experienced trainer responsible for transmitting the knowledge and skills to the trainee, using real machines or components. This methodology has several drawbacks. It makes extensive use of resources, to begin with, requiring an experienced trainer, usually a technician or even an engineer, to be available at all times during the training, and keeping the machine and other resources engaged in a process that does not directly generate value to the final products. This represents a high variable cost, because the total cost incurred for the training process is directly proportional to the number of workouts. In addition, traditional methodologies of training have a limited number of scenarios that can be trained, so tasks that involve risk or danger by their nature cannot be trained using this methodology.

To solve this problem, other alternatives may be considered to train the workforce in the industry, and virtual reality technologies is one of the most solid and most promising, as it has been successfully implemented for training in sectors where human life is at stake, as the medical, aviation and aerospace.

This paper is a continuation and improvement of [13], where virtual reality based training system has been proposed, giving excellent results and providing opportunities that are not available with the use of conventional methodologies. However, virtual reality has a limitation, no matter how realistic the virtual environment is, there will frequently be a difference with the real environment, depending on the specific training that can be large or small, and when the trainee is faced with the real task after training, this difference is reflected on its performance. This is because the transference phenomenona, due to the fact that skills sometimes cannot be transferred in a sufficient manner from the virtual environment to the reality. Because of this, not in all cases the virtual reality can fully replace the conventional methods for training, but if it helps to replace an important part of it. In contrast, augmented reality is a technology that is based on the real reality, where computer generated aids are added to a real environment, all the knowledge acquired in training can be used directly executing the task. The problem with augmented reality is that it presents many of the drawbacks of conventional methodologies, as it makes extensive use of resources.

To improve the training process as a whole, this paper presents an alternative training process that combines these two technologies, initiating the process with a virtual reality based training, obtaining all the benefits like low variable cost, and finalizing the training with augmented reality, where the trainee can finish the learning process.

2 Related Works

Some studies like [9], [7] and [4] have shown that virtual and augmented reality are very useful tools for special ability training, as well as parts recognition and assembly sequence remembrance.

Virtual environments have been widely adopted for training purposes with excellent results; in addition, virtual reality has taken a bigger role in computer graphics and is the subject of several studies aiming to improve the capabilities of current simulators to have higher levels of immersion and interactivity.

Virtual environments for mechanical assembly training, and generally all simulators must have a high level of immersion to achieve greater effectiveness in the process of learning or skills acquisition. Some studies like [16] show the key features for simulators to achieve high levels of immersion, and [9] mentions some of the generalities of these applications in assembly processes.

Several virtual reality systems have been proposed for applications such as mechanical design studies [3], evaluation of assemblies [15] and [11] and assembly path planning [12] among others. An important part of the study of these systems has focused on the following aspects: (i) in the development of new algorithms for collision detection, seeking greater accuracy and efficiency, so they can run in real time, (ii) in the CAD modeling of the parts used in the environment, to which is added weight and physical properties such as roughness of the material to make more realistic simulations and (iii) in the development of interfaces for interaction with virtual environments Some of these studies are [5] and [8].

Similarly, Augmented reality has also been the focus of study for numerous applications, like medical, manufacturing and visualization, as described in [4], or aircraft maintenance as described in [6], but the use of augmented reality for mechanical assembly training stills somehow unexplored. One of the main fields of research in AR is markerless tracking [1], since the markers may be inconvenient depending on the application.

Most of the studies on virtual or augmented reality focus on comparing this two technologies (or choose one over the other) rather than combining them into one process to obtain the benefits of both, and this is the main focus of this proposal, to combine these two technologies and propound a more complete and flexible training process for assembly operation in manufacturing companies.

3 Materials and Methods

3.1 System Development

The proposed training process consists of two stages; the first one, using virtual reality, where the learner acquires some of the skills to develop the task, and depending on the tasks nature, the portion of the process covered by VR may vary. Up to this point there would not be use of resources that are part of the production process, so that the expert and the machine would be available for other activities.

The next step is to continue with augmented reality training, where the learner comes into direct contact with the machine, all of its components and parts, and complements everything learned with the VR system. The following describes the development process of both training systems.

3.1.1 Virtual Reality System Development

The virtual reality training system has a modular architecture. It has been designed to be highly immersive, so a tracking device and stereoscopic vision were integrated into the system. The core module of the assembly training system was developed using Panda3D, an open source 3D game and simulation engine developed by Disney and maintained by Carnegie Mellon Universitys Entertainment Technology Center, and Python 2.7 as a programming language. This module is called the Assembly Trainer, and is the responsible of the entire logic of the system. The other modules are responsible of controlling each interaction device integrated with the system, those are, optical tracking and stereoscopic vision. A screenshot of the training system in 2D can be seen in Figure 1.

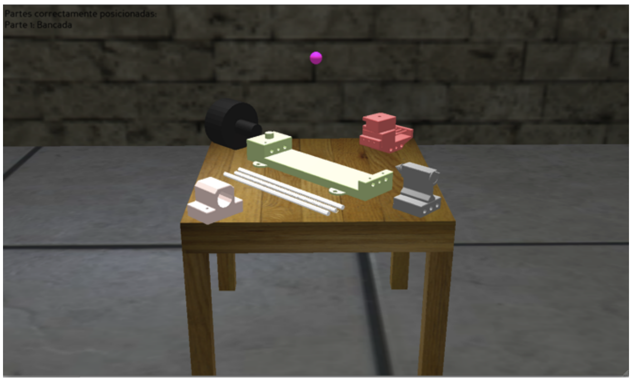

Figure 1: Screenshot of the virtual reality training system for mechanical assembly. This is the initial state with all parts separated.

The module that controls the interaction of the system with the optical tracking device is called Input Manager, and communicates directly with the tracking controller to obtain the data and pass it to the Assembly Trainer. The optical tracking system used is an OptiTrack FLEX: V100R2. The tracking system has 3 different cameras that capture the position of the marker from 3 different angles, and using that information it calculates the markers position in the workspace.

The Stereoscopic Manager is the module responsible of displaying the 3D image; it creates the double window and controls the two cameras that capture the images from two different angles. The Figure 2 shows the architecture of the training system.

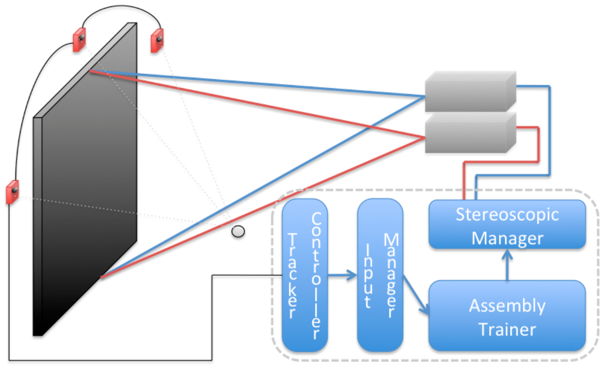

Figure 2: Architecture of the virtual reality training system. The "Input Manager" controls the interaction with the optical tracker, while the "Stereoscopic Manager" is responsible for sending the corresponding images to the projectors.

3.1.2 Augmented Reality System Development

The Augmented Reality System was built on ARToolkit, a software library for building augmented reality applications, using C++ as a programing language. The 3d models were made with the aid of Blender, an OpenSource software for graphics modeling and animation.

The logic of the application is described as follows: At first, the system captures the video input frame directly from the camera and processes the image in order to detect the markers (also called patterns), then it calculates the transformation matrix for the camera position and orientation relative to the pattern and finally draws the virtual models in the scene.

The idea of this part of the training process using AR is to allow the user to perform the task, which in this case is to assemble a milling machine, using the real parts, and not some computer generated models, so skills can be transferred in a much larger proportion. AR patterns were put over some specific pieces in order to display relevant information as the training session is developing. A picture of the real milling machine with the markers can be seen in Figure 3.

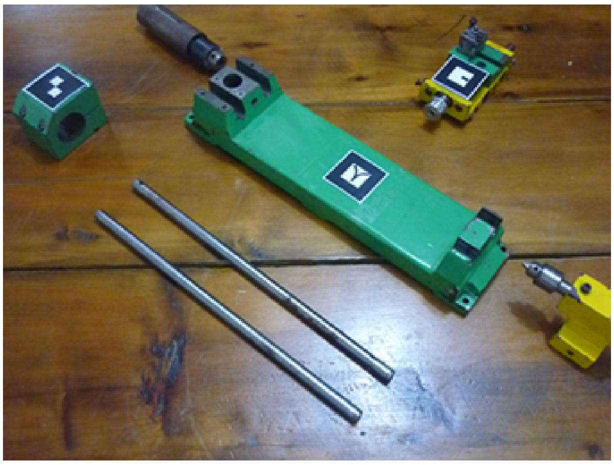

Figure 3: Photograph of the milling machine disassembled and ready to perform a training session using AR. Some parts have patterns attached.

The system recognizes a number of patterns associated with specific pieces of the machine on which the training is being done, and depending on patterns recognized at a given time and their position, it determines the stage of the training and thus shows the necessary information at that point, as shown in Figure 4.

Figure 4: Screenshot of augmented reality system during a training session.

3.2 Experimental Design

To validate the effectiveness of the training process by combining virtual reality and augmented reality, a series of tests were carried out of which process will be described below. From a single population mainly conformed by EAFIT students with no previous experience in the assembly of a milling machine or mechanical assembly in general, subjects were randomly selected to conform the experimental and control groups.

The trained task consists in assembling a milling machine. At the beginning of the process, each participant, regardless of which group they belong to, had to perform the assembly task using the real components to determine its initial skills. Likewise, after completing the training, participants had to perform the assembly task again to determine their final skills. After the initial assessment, the experimental group went trough 5 training sessions using the virtual reality training system, and then trough 3 training sessions using the augmented reality training system. The control group went trough 8 training sessions using the conventional methodology, using the real components of the machine, plus the 2 assessment sessions.

4 Results

The average time of each training session was plotted with the data collected from all the training sessions of the subjects. Figure 5 shows the average learning curve for both methodologies.

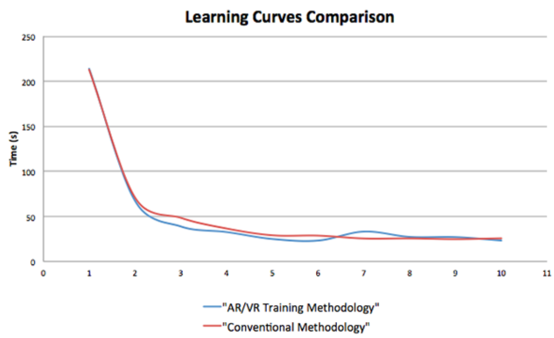

Figure 5: Learning curves comparison, note that session 1 and 10 are the initial and final assessments, for the RV/AR methodology: sessions 2 - 6 (VR), sessions 7 - 9 (AR)

The variables compared between the two samples were the time reduction. The experimental group has an average time reduction $\bar{X}$ = 190.57 seconds with S_1^2 = 11614.24, while the control group has an average time reduction $\bar{Y}$ = 186.90 with S_2^2 = 12463.05. The conclusion of the hypothesis test with $\alpha = 0.05$ is that the difference is not statistically significant, meaning that there is not enough evidence to state that the difference of the two means is different from zero, in other words, the hypothesis that the two means are equal cannot be rejected.

Analyzing Figure 5, it can be clearly seen the performance reduction of the trainees in session number 7; session number 6 was realized using the virtual reality training system, while session number 7 was realized using the augmented reality training system, this shows two things, that the skills the trainees obtained with the VR system could not be entirely replicated in a real environment, but it also shows that the VR training system was able of replacing a big part of the training process, and transferred the skills in a significant manner. Likewise, if session 9 and 10 are compared, it can be noticed that the difference between both times is practically inexistent, and considering that session 9 was performed using the AR system and session 10 was the final assessment, it confirms that the performance achieved at the end of the training with AR can then be replicated in normal conditions.

5 Conclusions

From the initially proposed objectives, and considering the results it is possible to conclude:

- Combining virtual and augmented reality into a single training process is as effective as conventional methodologies, moreover, it allows a more efficient use of resources and greater flexibility in the type of companies can benefit from these technologies, as it better fit their needs than when using only one of them.
- Virtual reality and augmented reality have different applications under certain conditions, making one of them better for some cases, and the other one better for other cases, so they can complement each other.

6 Future Work

During development, several aspects that could be included in future work to improve the process were identified, these include:

- Develop other RV and AR systems not only to help companies to improve their training processes but also systems capable of helping to improve the productivity of the companys processes.
- To facilitate collaborative tasks is possible to add networking capabilities over the Internet, where trainees can practice tasks that require the interaction of several people and obtain teamwork skills.
- In order to enhance the user experience in augmented reality, markerless techniques may be explored.

References:

[1] Seok-Han Lee Ahyun Lee, Jae-Young Lee and Jong-Soo Choi. Markerless augmented reality system based on planar object tracking. In *Frontiers of Computer Vision (FCV), 2011 17th Korea-Japan Joint Workshop on*, 2011.

[2] Metin Akay and Andy Marsh. *Information Technologies in Medicine, Volume 1, Medical Simulation and Education*. Wiley-IEEE Press, 2001.

[3] Rajarathinam Arangarasan and Rajit Gadh. Geometric modeling and collaborative design in a multi-modal multi-sensory virtual environment. In *In DETC 2000*, 2000.

[4] R. T. Azuma. A survey of augmented reality. *Presence: Teleoperators and Virtual Environments*, 6(4):355–385, 1997. Cited By (since 1996): 787.

[5] Marvin M. Chun and Yuhong Jiang. Implicit, long-term spatial contextual memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 29(2):224 – 234, 2003.

[6] F. De Crescenzio, M. Fantini, F. Persiani, L. Di Stefano, P. Azzari, and S. Salti. Augmented reality for aircraft maintenance training and operations support. *IEEE Computer Graphics and Applications*, 31(1):96–101, 2011.

[7] A. Dnser, K. Steinbgl, H. Kaufmann, and J. Glck. Virtual and augmented reality as spatial ability training tools. In *ACM International Conference Proceeding Series*, volume 158, pages 125–132, 2006.

[8] Nobutaka Endo and Yuji Takeda. Selective learning of spatial configuration and object identity in visual search. *Attention, Perception, amp; Psychophysics*, 66:293–302, 2004. 10.3758/BF03194880.

[9] S. K. Gupta, D. K. An, J. E. Brough, R. A. Kavetsky, M. Schwartz, Ra K. Gupta, Davinder K. An, John E. Brough, Robert A, Maxim Schwartz, and Atul Thakur. A survey of the virtual environments-based assembly training applications, 2008.

[10] Satyandra K. Gupta, Davinder K. Anand, John E. Brough, Maxim Schwartz, Satyandra K. Gupta, Davinder K. Anand, John E. Brough, Maxim Schwartz, and Robert A. Kavetsky. A safe, cost-effective, and engaging approach to trainingtraining in virtual environments a safe, cost-effective, and engaging approach to training, 2008.

[11] Uma Jayaram, Sankar Jayaram, Charles DeChenne, Young Jun Kim, Craig Palmer, and Tatsuki Mitsui. Case studies using immersive virtual assembly in industry. *ASME Conference Proceedings*, 2004(46970):627–636, 2004.

[12] A. Mikchevitch, J.-C. Léon, and A. Gouskov. Numerical modeling of flexible components for assembly path planning using a virtual reality environment. *ASME Conference Proceedings*, 2003(36991):1115–1124, 2003.

[13] Trefftz H. Peniche A., Diaz C. and Paramo G. An immersive virtual reality training system for mechanical assembly. In *Recent Advances in Manufacturing Engineering, Proceedings of the 4th International Conference of Manufacturing Engineering, Quality and Production Systems (MEQAPS 11)*, pages 109–113, 2011.

[14] Mateusz Skoczewski and Hitoshi Maekawa. Markerless pose tracking based on local image features and accelerometer data. In Hamid R. Arabnia and Leonidas Deligiannidis, editors, *CGVR*, pages 194–199. CSREA Press, 2009.

[15] Huagen Wan, Shuming Gao, Qunsheng Peng, Guozhong Dai, and Fengjun Zhang. Mivas: A multi-modal immersive virtual assembly system. *ASME Conference Proceedings*, 2004(46970):113–122, 2004.

[16] D. Weidlich, L. Cser, T. Polzin, D. Cristiano, and H. Zickner. Virtual reality approaches for immersive design. *CIRP Annals - Manufacturing Technology*, 56(1):139 – 142, 2007.