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Augmented Reality- The third way for new technologies in welding education

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Abstract:
New technologies evolve to the welding educational use. Existing commercial systems use different approaches to support the beginner for getting started in the subject of welding. Virtual reality or pure tracking of the welding torch are two commercial approaches. Virtual reality (VR) system can be subdivided into pure VR systems using a gaming like environment with 3D video-see-through Head Mounted Displays (HMD) and into monitor based system where the virtual environment is displayed in 2D, interfaced with a welding torch like device.
A third approach is presented in this article with the ISMAS system by using the paradigm of Augmented Reality. The natural view onto the scene is overlaid with artificial data like a virtual welding seam. The trainee sees the physical welding piece with a virtual welding seam blended into his view by an optical-see-through HMD. By that the interaction with the environment is as natural as it can be. The tracking of the welding piece and the welding torch-like interface is based on 2D labels attached to them. These labels are registered by a camera which is mounted in a welding helmet, so that the pose of both is tracked in real time. The camera fulfils besides the tracking as well the video documentation of the exercise.
As an option the system may be used during real welding to broaden the integration into the educational process from pure virtual welding to documented real welding.

1 Introduction

Learning and teaching welding is a track of theory and manual experience. The scholar has to learn by producing welding seam over seam. A highly experienced teacher needs to show and let him feel the nature of the different welding processes. The visual sense gives him information about the pose of the welding torch affecting the welding bed and the shape of the welding arc. The sense of hearing gives the feedback about the process itself respectively the droplet transfer.
For this teaching process new training system are developed to improve the learning curve related to time and money. The scholar shall be equipped with system that gives him the opportunity to learn basic handling without consuming material and with minimizing the teacher supervised time.
A concise overview about these new technologies related to the training of manual welding is given in this article. Different approaches to support the welding training are related to the impression the user gets.

2 Mixed Reality Continuum

For standard processes boundaries exist for the speed as well as the travel and working angle. Although a wide variety of materials and processes exist, the first step in learning how to weld are made by pre-defining the pose of the welding torch for the trainee, so that he retrieves a good result for a standard situation. This kind of first step can be transferred by using a torch tracking system to a technical system, which trains the constant and right handling of a welding torch. Systems like the welding trainer from the Schweißtechnische Lehr- und Versuchsanstalt Halle[1]. It uses a LED based tracking system which is supported by a real low current TIG welding arc for torch tracking and handling evaluation.
Tracking just the torch does not interfere the real handling of the welding process; it is real. The expression “Mixed Reality” describes a continuum from reality to the virtual reality. The virtual reality is a world where everything of the environment which one can see, has been generated by a computer. It can be accessed with video glasses or so called video-see-through **H**ead **M**ounted **D**isplay (HMD), which supplies the user with rendered view onto the computed artificial graphical world. By tracking the pose of the user’s head, a natural view while turning the head or looking up and down may be experienced. The user turns his head left and he sees the virtual world left of him. In between these two ex-

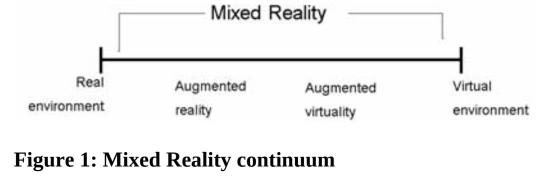

Figure 1: Mixed Reality continuum

[1] Schweißtechnische Lehr- und Versuchsanstalt Halle GmbH; D-06118 Halle (Saale), Germany

tremes: reality and virtuality exist some intermediate levels of reality/virtuality. Paul Milgram presented this continuum in his paper (Paul Milgram, 1994) similar to
Figure 1. One step in between, is the so called augmented reality (Azuma, 1997) (R.Azuma, 2001). Here the user sees the reality upgraded with some artificial graphical object.
Many ideas have been proposed for the application in industrial environments (Regenbrecht, 2007), (S.K. Ong, 2007).
Imagine two welding torches on the workbench. One is real and lying on the bench and the second is calculated by the computer and somehow blended into the view. This kind of blending can be done with video glasses which use transparent screens. The user can see the reality while graphical objects may be displayed on the transparent screens. The continuum of mixed reality goes further depending on the proportion of reality to virtuality. The next level is the Augmented Virtuality which is dominated by a very high portion of virtual objects. The reality is only a decoration in the view of the user. Like video conferencing systems where 3D-Avatars are sitting around a table and the head of the avatar is a graphical duplicate of a person filmed by video camera transported via internet from the middle of nowhere.

3 Mixed Reality Welding Trainer

Going into the direction of the second extreme in the mixed reality continuum, the Virtual Reality Welding trainer try to cover more senses than the visual feedback while handling a torch. They substitute the real view of the welder with a virtual view onto the welding piece. These systems distinguish between the use of pure virtual reality using video glasses and monitor based projection.
A monitor based projection delivers a 2D view onto the (virtual) work piece. Like a monitor build into the workbench appears a graphical metal sheet on this screen. The scholar welds virtually on the screen. If the screen is mounted upright or upside down different positional welding may be done. The torch pose is tracked and the position of the monitor is known. So beside the pose, the distance between monitor and torch can be computed. This data is fed to an algorithm which models the welding seam and results in a graphical rendered seam on the monitor. The virtual welding seam is directly shown at the correct position related to the torch movements.

Figure 2 Welding torch with marker

Another step ahead by substituting the real world with virtual impressions is to build a computer generated virtual world (Kenneth Fast, 2004). It may consist of all interior equipment of a workshop. Like a virtual work bench with a virtual metal sheet lying next to the virtual welding torch. As introduced the entire virtual reality (VR) of the workshop can be accessed by the scholar using pose tracked stereo video goggles. The welding torch on the workbench moves like the real tracked counterpart in the hand of the scholar.
Inside this video game like environment the user may experience more virtuality than the monitor based systems can. For instance the computer generated dark view through a welding helmet is something which can be experienced by covering the users head with an HMD. Beside this visual input for the user it enable earphones to produce auditive feedback.
Beside the monitor based and pure VR another type of teaching system is conceivable. Such a system augments the reality by artificial computer generated objects. Augmented reality aims for seamlessly integration of the virtual world into the real world. The Augmented Reality System TEREBES[2] grabs the scene during welding with two video cameras and augments the video with process data. This composition is shown on a stereo video goggle. The two independent video channels are connected each with the left and right channel of the video glasses. The distance between the cameras is adjustable onto the eye distance of the user. So a good spatial recognition is remained. This system focuses on the prospects of supporting professional welder with additional scale information during work (B.Hillers, 2004), (M. Park, 2007).

Figure 3 HMD with tracking camera

For supporting the scholar a system called ISmaS[3] has been developed and is presented here in depth. It enables the process of virtual welding in the real word. ISmaS is a classical AR system where the user sees the world by an optical-see-through HMD.

[2] Tragbares Erweitertes Realitätssystem zur Beobachtung von Schweißprozessen
[3] Integriertes Schulungssystem für manuelles Schweißen

The computer generates virtual objects and overlays them seamlessly onto the scholars real natural view.

Referring to the welding training application, the user sees the real work piece and holds the real welding torch in his hands. While virtual welding the pose of the torch and the work piece is extracted and fed to a welding seam model which delivers a rendered welding seam. By that the position of the work piece relative to the scholar is known and the computer generated seam is blended into the scholars view by the HMD. So the real work piece and the virtual welding seam can be seen at once.

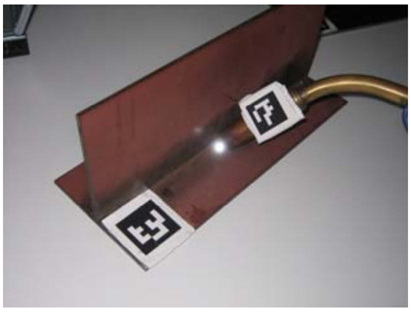

Figure 4: Welding Torch and Work Piece with Optical Marker

The tracking of the welding torch and the work piece is done by optical markers attached to the objects. The size and projective distortion of the rectangular marker onto the camera image, do give information about the distance and pose of the marker relative to a camera (Kato, 1999). In Figure 2 a welding torch with an attached optical marker is shown. It is tracked by a camera mounted on the HMD as shown in Figure 3. The transformation from the cameras view to the users is a very critical issue. This transformation changes with every user and as well with every put on and off. The calculation of this transformation has to be done with every use of the HMD. It is not very tedious or long but it bothers by its permanent need.

Figure 5: Real View with Virtual Seam

The work piece is tracked using a similar marker. The relative pose of the torch to the work piece is always known, as the camera is the base coordinate system for both measurements. Based on this information an algorithm which forms the seam model produces the shape of seam It is a volumetric model based on heuristic data and extracted from welding experiments for fillet and groove welding. An overlaid seam model can be seen in Figure 5.

During virtual welding the scholar is supported by a scale which is virtually attached to the welding torch. It indicates the optimal pose of the torch during welding for the travel and working angle (see Figure 6). So the scholar may learn the first steps of torch handling.

The ISmaS system includes some features similar to the pure virtual systems. The torch and the work piece movement can be transferred onto a virtual torch and virtual work piece. So a replay of the scholars view can be done in parallel to the view onto a virtual work piece with the virtual welding. The virtual work piece has the advantage that it can be turned around, moved and zoomed to the needs of the viewer. The free choice of the optimal view onto the virtual scene which was simultaneously produced based on the welding torch movements of the real welding, supports the effect of teaching and self-reflection.

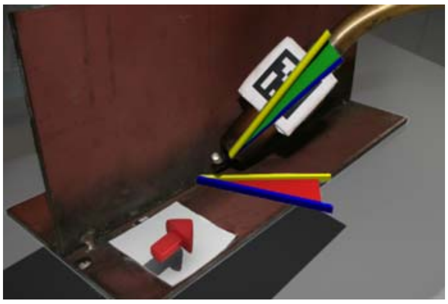

Figure 6: Indicators for Optimal Torch Handling

A real welding can be integrated in this concept if the HMD is omitted and a protection helmet with a mounted camera is used instead. A specialized high dynamic range camera based on C-MOS technique maps the high dynamic light conditions of the scene during welding. In order to minimize the difference between the welders view and the cameras viewport, the camera is positioned between the eyes on the darkening filter glass (see Figure 7). The markers have to be heat resistant due to the real welding arc. They are tracked by the camera of the welding protection helmet.

Now the video of the real welding can be replayed. The

Figure 7:Camera Welding Helmet

virtual welding, which should be in the ideal case identical or equivalent with the result of the real welding seam, can be shown in parallel.

4 Conclusion

The ISmaS system uses the approach of Augmented Reality in order achieve support in the most realistic way. Without abolishing the real view onto physical objects, the implemented concept supports the scholar with a high amount of reality. While tracking the torch and work piece the replay of the virtual welding is available. In contrast to other approaches of pure virtual systems the ISmaS concept includes the second step of welding training with real weldings. The real process can be tracked and reviewed by video and virtual views.

5 Credits

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