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Augmented Reality Integrated Welder Training for Mechanical Engineering Technology

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Dr. Eisazadeh joined Old Dominion University (ODU) in Fall 2018. Before joining ODU, he was a faculty member at the County College of Morris for one year, and a faculty member at the Chabahar Maritime University over four years. Dr. Eisazadeh received his Ph.D. (2017) in Mechanical Engineering from Clarkson University in New York, his MSc (2005) in Manufacturing Engineering from Tehran University, and his BS in Manufacturing Engineering from Mazandaran University. He has several years of research and teaching experience, and he is a member of the American Welding Society. His work involves studying residual stress formation in dissimilar weld and additive manufacturing using finite element modeling and neutron diffraction measurement. He has examined and practiced various modern techniques to mitigate weld residual stresses and their consequences. Through his work, he has presented at several conferences and co-authored papers on the reduction of residual stress in dissimilar metal weld.

Aditya Akundi (Assistant Professor)

ADITYA AKUNDI is an assistant professor in the department of Informatics and Engineering Systems at theUniversity of Texas Rio Grande Valley (UTRGV). Dr. Akundi received hisPhDat the University of Texas at El Paso (UTEP) in 2016. In his doctoral thesis, he investigated the use of information theory to understand and assess complex socio-technical systems. Before joining UTRGV, he worked as a research assistant professor in the Industrial Manufacturing and Systems Engineering department at UTEP for a period of three years from 2016 to 2019. Dr. Akundi published several papers in the field of systems modeling, systems testing, assessing INCOSE Handbook, model-based systems engineering, and engineering education. His research has received funding from the National Science Foundation (NSF) and is currently an I-DREAM4D Department of Defense (D0D) Fellow at UTRGV.He is a member of INCOSE and ASEE. He received the outstanding junior faculty award from the ASEE Manufacturing division in 2017 and 2018 and currently serves as the program chair of the ASEE manufacturing division.

Augmented Reality Integrated Welder Training for Mechanical Engineering Technology

The shortage of welders is well documented and projected to become more severe for various industries such as shipbuilding in coming years. It is mainly because welding training is a critical and often costly endeavor. This study examines the training potential using augmented reality technology as a critical part of welder training for mechanical engineering technology students. This study assessed the performance of two groups of MET students trained with two different methods. One group received training with the traditional method in three sessions. The second group acquired training initially with an augmented reality welding system for three sessions. Then, they were exposed to actual welding training. The results demonstrated that students trained using augmented reality had training outcomes that surpassed those of traditionally trained students. Lastly, the material cost impact of the augmented reality group was significantly less than that of the group with traditional welding training.

Introduction

Welding is a joining process that combines two or more materials permanently with the use of heat, pressure, or combined[1]. The welding processes are executed using a mechanized machine like a robot or human; in the latter case, it is called manual welding. Despite the increase of robots in the welding industries, manual welding is still a must for many industries such as shipyards and constructions. However, manual welding is one of the most challenging processes to pass from one welder to another as it requires trainees to spend a tremendous amount of time learning welding skills and synchronizing hands with eyes. In addition, the training process requires a lot of investment, such as time, teachers, welding raw materials, welding gas, and other consumable materials[2,3]. Moreover, training should be performed with proper supervision to avoid human error to provide a safe environment as it can be harmful to health because of ultra violet light, smoke, infrared light, and, most importantly, heat, as shown in Figure 1.

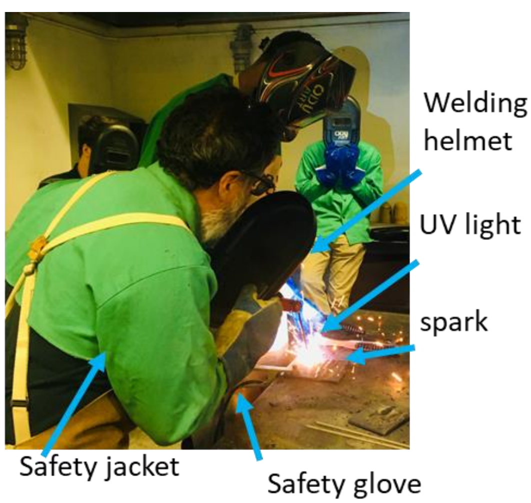

Figure 1: Student performing actual MIG welding process

Augmented Reality, which was developed in the last two decades, offers great potential in various industries. Academia is one of the environments that has already adapted this technology to take advantage of it for both research and education purposes. The use of AR has been grown in welding education since it can be employed to train students to acquire the basic knowledge and skill to perform welding in a safe environment while saving a significant training cost.

This study examines the training potential using augmented reality technology as a critical part of welder training for mechanical engineering technology students. This study assesses the performance of two groups of MET students trained with two different methods. Lastly, the potential and benefits of this technology is presented.

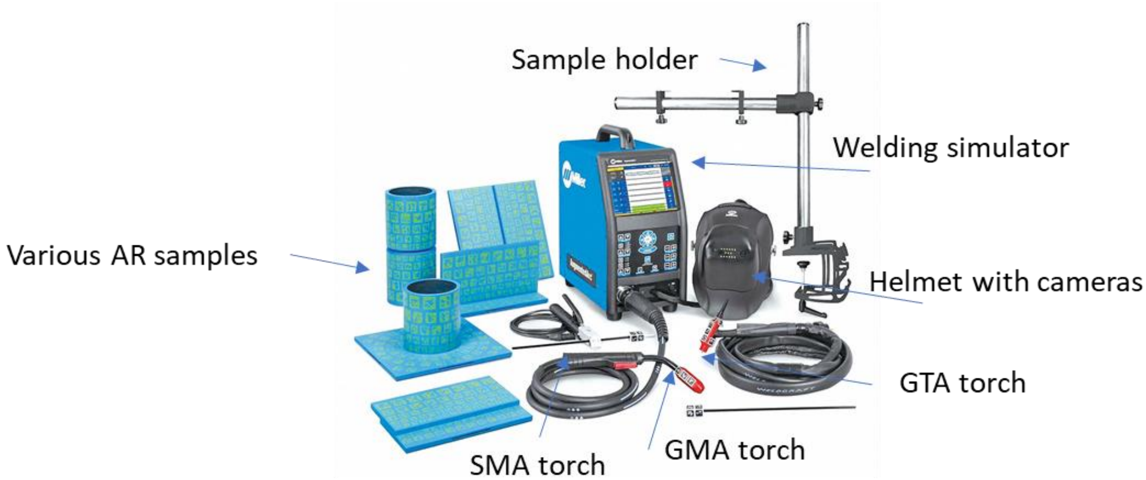

Figure 2: Augmented Reality Welding Simulator and Accessories

Augmented Reality Welding Simulator and Accessories

Augmented Reality Welding systems utilize advanced computer simulation techniques with artificial vision technology to create a realistic welding environment. This simulator has an LCD to provide instructors or students feedback about the welding performance, see Figures 2 and 3.

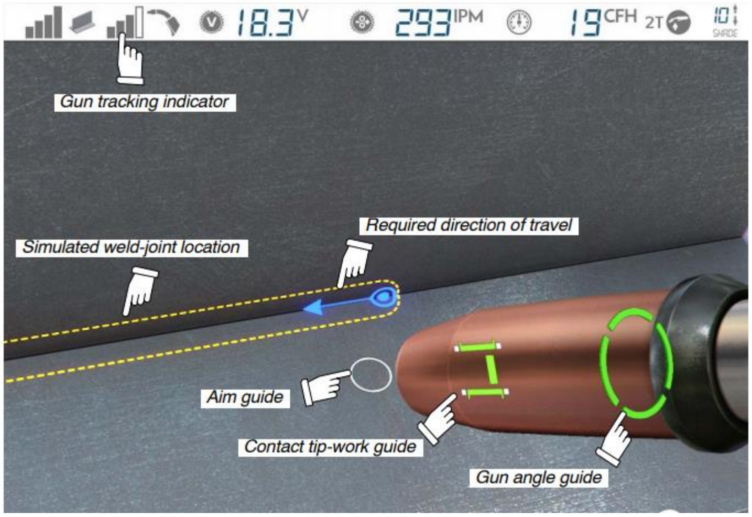

Figure 3: A typical screen of the augmented reality welding system that provides real-life welding experience to students, illustrating live information about work angle, travel angle, arc length, and travel speed

Welding Helmet

The Augmented Reality welding helmet, shown in Figure 2, has two cameras connected to a 5-inch led screen to deliver a real welding experience to a welder. These two cameras create a real-time augmented reality by superimposing the welding accessories like workpieces, guns, filler rods to a real welding environment.

Augmented Reality SMAW Electrode

The SMAW electrode, shown in Figure 4, looks very similar to an actual electrode in all features like shape, weight, and size. It is placed within the electrode holder connected to the welding simulator. The holder retracts the electrode during welding to simulate the electrode consumption in real welding.

Figure 4: Augmented reality welding torches and electrodes for SMA, GTA ad GMA welding processes

Augmented Reality GMAW Electrode

MIG/FCAW welding is a semiautomatic process that uses a continuous wire feed as an electrode and an inert (MIG) gas mixture to protect the weld from contamination. The wire can be solid (GMAW) or cored (FCAW). The Augmented Reality GMA/FCA welding gun, shown in Figure 4, simulates GMA/FCA welding processes. The student starts by selecting the shielding gas, wire type, and diameter. After the exercise has begun, the student adjusts the wire feed speed on the simulator.

Augmented Reality GTA Electrode

GTA welding process uses a nonconsumable electrode to generate heat and melt the base metals. The student may add filler by dipping the rod into the weld joint, just as in real welding. Augmented Reality GTA systems include filler rod markers on the GTAW torch, shown in Figure 4.

Welding Course in Mechanical Engineering Technology at University A

University A started to offer the Introduction to Welding Technologies course in the mechanical engineering technology program in 2014. The course articulates an introduction to conventional and non-conventional welding processes initially. Since the course is intended to provide the students with a basic understanding of the various welding processes, welding terminology, joints, symbols, welding defects, and equipment, only the most essential manual welding processes like SMAW, GTAW, and GMAW processes are taught in this course. The college of engineering and technology at University A did not have a welding laboratory until 2021. To improve students' learning, the instructors had arranged several visits to a community college nearby to expose them to actual welding processes in 2017, 2018, and 2019. Although the training was beneficial for students, since most of them had not acquired academic training before, there were still some challenges in terms of commuting to an off-campus location. Many students at Univerisity A live in on-campus housing and do not have cars for travel. In 2021, the college of engineering and technology opened a new maker laboratory for students with a large space dedicated to welding. The instructor taught the three mentioned welding processes in the new welding space. In addition, Engineering Technology Department purchased an Augmented Reality Welding System in 2021. The instructor used the AR welding system and actual welding machines to teach the courses in 2021. Figure 5 shows a typical weld practice made by a student.

In addition to performing welding, the undergraduate students at University A were also exposed to learn metallography of welds through experiments. At the beginning of the semester, all students are provided with a project outline and detailed steps. This project typically lasts at least eight weeks. The main objective of this project is that students learn how to analyze the weld by examining the microstructure of welds. They are trained to produce professional micrographs through various polishing steps and etching. They become skilled in taking quality macro and micrographs of weld cross-sections. More importantly, they will be practiced to take micro hardness reading on the weld surface and weld boundaries. The project steps are summarized as follows:

1- Project assigning
2- Create welds
3- Cut specimens and bend tests
4- Mount specimens
5- Polish specimens
6- Etch specimens
7- Image specimens
8- Hardness test specimens

a. A typical student weld practice without AR training

b. A typical student weld practice with AR training

Figure 5: GMA weld practices produced by student with and without augmented reality welding training

Study goal

This study aimed to explore augmented reality technology's effectiveness in improving learning and education related to the manual welding processes like GMAW, SMAW, and GTAW processes for mechanical engineering technology students at University A. For this study, Augmented Arc Welding Training System from Miller Electric was employed, which is capable of training all the welding as mentioned above processes.

Methods

This study used the outcomes of welding assignments from two classes offered in 2019 and 2021. In 2019, an assignment was designed to evaluate students learning after three sessions of welding practices. Each session focused on one of the three GMAW, SMAW, and GTAW processes. Although three weld joints, bead-on-plate, T-weld, and butt-weld, only the former type was tested due to unsophistication of its type. Each student was provided a plain structural steel plate to create one weld. Several factors were considered when grading the students' weld tests, such as the width of the bead, welding velocity, arc distance, and consistency.

In 2021, students acquired three augmented reality welding practices sessions before learning the actual welding processes in action. In these sessions, students received scores for their practices which were based on work angle, travel angle, arc length, and travel speed. The attractiveness of augmented reality welding systems is that the operators' gestures and motion can be quantified, which was a very challenging task prior to this technology. After augmented reality welding training, students were taught GMAW, SMAW, and GTAW processes in a three-hour session. Similar to 2019, three weld joints, bead-on-plate, T-weld, and butt-weld, were employed for all training processes, but only the former type on a plain structural steel plate was tested due to consistency with the previous group.

The results of students' performance for each process when used augmented reality welding system is shown in Figures 6, 7, and 8. For example, weld aim refers to where the weld bead is formed in relation to the center of the weld joint. The suitable distance from the tip of the electrode should be at the weld coupon, which is termed arc length. Work and travel angles are the appropriate horizontal and vertical angles the welder should keep between the electrode and weld coupon. Travel speed is the appropriate horizontal speed that a welder should move the electrode across a weld joint. These feedbacks allow students to analyze his/her gestures, electrode feeding rate, and torch speed. As a result, they can improve their performance without instructor supervision.

Figure 6. SMAW process with AR

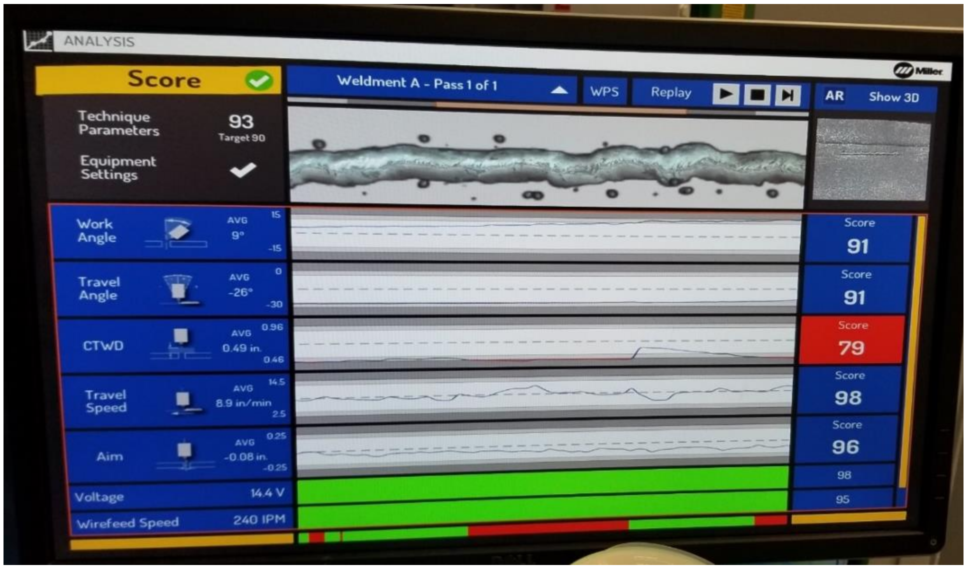

Figure 7. GMAW process with AR

Figure 8. GTAW process with AR

Results and Discussion

The performance criteria for this study were weld quality scores provided by the instructor. The instructor visually evaluated the quality of the welds like cracks, porosity, undercut, with a focus on arc strikes and bead consistency. The grades were based on 100 points. Depending on the type and severity of defects, 2 to 10 points were taken off from 100 total points. Then the digit grades were converted to letter grades. The letter grades for the 2019 and 2021 groups are illustrated in Figures 9 and 10, respectively. There was no welding training in 2020 because all classes were held online due to the Covid-19 virus spread.

As shown in figure 9, six students out of fifteen received the letter A/A- in the 2019 group. In other words, 40% of the class met the training objectives. Eight of them received B/B+/B-. On the other hand, ten students out of twenty received the letter A/A- in the 2021 group. That is to say, 50% of the class met the course objectives, which was a significant increase. Overall, from the course-objective standpoint, the augmented reality welding training sessions helped MET students build an acceptable background prior to the actual welding process.

There are essential viewpoints that should be considered when researching the influence of augmented reality welding systems. An important benefit of using this technology for our department was that the number of enrollments for the welding course was increased when students realized the welding lab was equipped with this new technology. This is because many students are intimidated by the harsh environment of the welding process due to its smoke, heavy welding torch, heat, and high-density light. This technology provides a safe environment for students, which is very important for beginners who have never welded prior to this class. The other benefit for the ET department was that a significant material and cost were saved since augmented reality welding systems only use electricity. Overall, students reflected very positive feedback verbally and in writing at the end of semester.

Authors are aware that there are many variables that could affect the results of this comparison, such as students' age difference in the two groups, the population of students, genders, dominant hand, average number of hours that student spends per day playing video game, whether the student welded before. As such, in the future study, authors will conduct a study to consider all aforementioned factors with a much larger students' population across the college of engineering and technology.

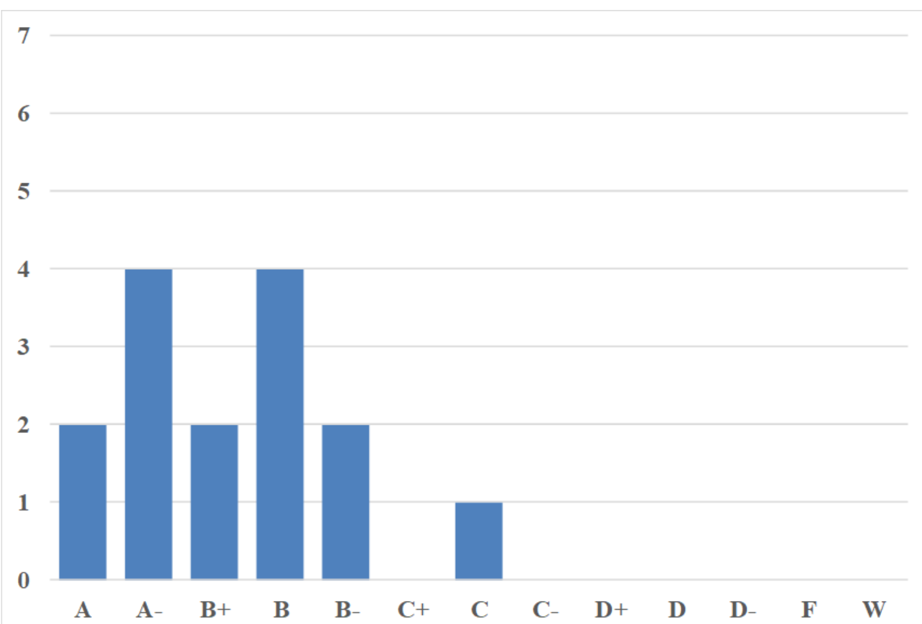

Figure 9. Grade distribution of Welding assignment

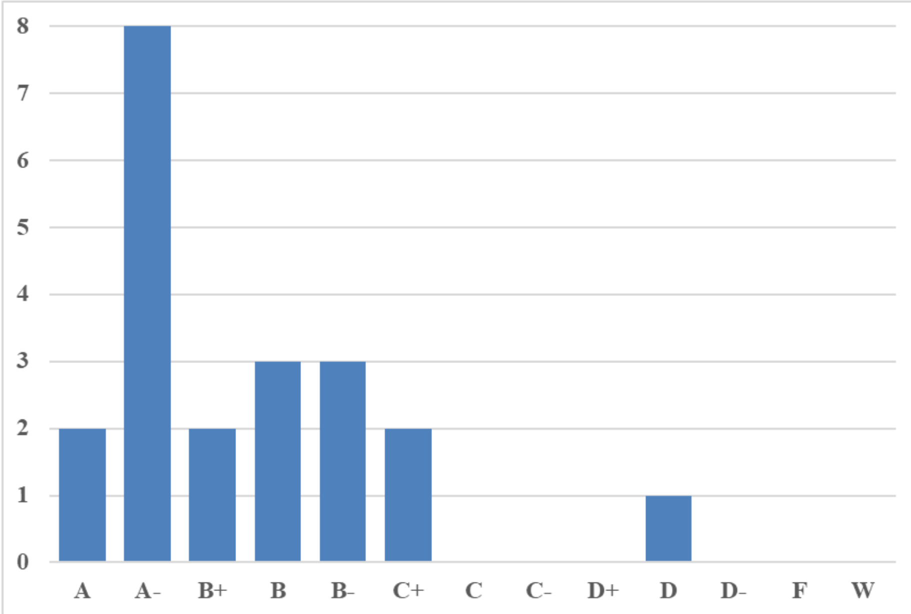

Figure 10. Grade distribution of Welding assignment

Conclusion

This study examined the training potential using augmented reality technology as a critical part of welder training for mechanical engineering technology students. This study assessed the performance of two groups of MET students trained with two different methods. The performance criteria for this study were weld quality scores provided by the instructor.

The instructor visually evaluated the quality of the welds like cracks, porosity, undercut, with a focus on arc strikes and bead consistency. One group received training with the traditional method in three sessions. The second group acquired training initially with an augmented reality welding system for three sessions. Then, they were exposed to actual welding training. 40% of the 2019 class met the welding training objectives. 50% of the 2021 class met the course objectives, which was a significant increase.

There are essential viewpoints that should be considered when researching the influence of augmented reality welding systems. An important benefit of using this technology for our department was that the number of enrollments for the welding course was increased when students realized the welding lab was equipped with this new technology because this technology provides a safe environment for students, which is very important for beginners who have never welded prior to this class. Lastly, the material cost impact of the augmented reality group was significantly less than that of the group with traditional welding training.

Overall, students reflected very positive feedback verbally and in writing at the end of semester. In the future study, authors will conduct a study to consider factors like students' age difference in the two groups, the population of students, genders, dominant hand, average number of hours that student spends per day playing video game, and whether the student welded before with a much larger students' population across the college of engineering and technology.

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