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Improving the quality of welding training with the help of mixed reality along with the cost reduction and enhancing safety

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ABSTRACT

Welding is widely used in all industries, and its demand is drastically increasing. Today, all sectors of engineering need quality welders to meet their standards. Welders need years of experience and knowledge to meet those standards. They require lots of training, equipment, tools, and safety standards to master the welding skill. The cost of training is very expensive as they will be practicing every day with different materials. The purpose of this project is to train them in a new merged-up environment of the virtual and real world. As a result, this method would reduce training costs and enhance the safety of the users. This method is a medium that helps users to have a better understanding of welding operations and gives them the confidence to perform proficiently in reality along with the elimination of risk, liability, and injury.

1. Introduction

Welding is a common process of joining two or more metals using a large variety of applications. Welding is extensively used in the industrial manufacturing area. Due to which there is a high demand for welders in the present day as compared to the past. There are a wide variety of different processes with their own techniques and application for industry. These include: 1) Arc; 2) Friction; 3) Electron Beam; 4) Laser and 5) Resistance. All of these processes have their own techniques, such as the use of filler material, mechanical friction, which does not require filler metals as well as shielding gas, a beam of high-velocity electrons, laser to provide a concentrated heat ideal, and heat delivered between two electrodes. Arc welding includes a number of common manuals, semi-automatic and automatic processes. These include inert metal gas (MIG) welding, stick welding, inert tungsten gas (TIG) welding, gas welding, active metal gas (MAG) welding, flux-cored arc welding (FCAW), gas metal arc welding (GMAW), submerged arc welding (SAW), shielded metal arc welding (SMAW) and plasma arc welding. Welding is one of the important and often used processes in the industry, and its usage ranges from the food industry to aerospace and from precision tools to shipbuilding. The human's need for modern, light, firm, and steady connections in recent years, especially the recent 20 years, has developed this skill rapidly, and the governments have invested heavily in this area. There is a fast development of this skill due to humans' competition in nuclear sciences which must target only at peace. Welding is among dangerous careers, and the related workers are exposed to many risks. The detention and refusal of these threats play a significant role in their health and making their environment healthy. On the one hand, welding is dangerous, laborious, and harmful occupational processes. In welding operations, metal pieces get connected using heat or pressure, or both. In other words, welding is the connection of metal pieces with the help of welding filler metal and heat or pressure (Zamanian et al., 2015). Welding is also a hazardous process. Burn to the skin, flash burns to the eyes, and fire are some of

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the more immediate and acute hazards. Fumes are solid particles that originate from welding consumables, the base metal, and any coatings present on the base metal. Despite the advance in control technology, welders continue to be exposed to welding fume and gases. The chemicals contained in these fumes and gases depends on many factors: 1) type of welding being performed; 2) the material of the electrode; 3) type of metal being welded; 4) presence of a coating on the metal; 5) time and severity of exposure; and 6) ventilation (Ashby, 2002).

Welding is one of the key components of numerous manufacturing industries, which pose potential physical and chemical health hazards. Welding fumes consist of a wide range of complex metal oxide particles which can be deposited in all regions of the respiratory tract. The welding aerosol is not the homogeneous ad is generated mostly from the electrode wire. Welding procedures may result in the production of various gases (metal oxides, CO_2, CO, O_3, NO_2, hydrocarbons) and welding fumes (Chadha & Singh, 2013). Welding fumes, as well as grinding and polishing, arc radiation and chemical interactions within the fume, can create all hazards for welders. Studies have shown that the levels of respiratory exposures depend on the type of welding performed, the type of electrode, base metal, base metal coating, flux and shielding gas used, the welding voltage and amperage, and the position of the welder (Safety et al., 2006). The health risks associated with welding gases and fumes are also determined by the length of time one is exposed to them, the type of welding engaged in, the work environment, and the protection employed (Chauhan et al., 2014). While going for weld, welders must have proper safety instructions and knowledge to avoid any injury and risks. When mistakes or carelessness happen around welding equipment, they can have severer consequences. The different safety measures include: 1) dress for the occasion; 2) keep your workspace safe; 3) avoid electric shock; 4) be attentive and focus on your work; 5) avoid fire hazards; 6) use the hierarchy of hazard controls. The objective of training for a long period is to get certified after giving the test. The test is conducted by a certified welding inspector that will determine if the welder can produce a sound quality weld up to the code or welding procedure needed for a company or a particular industry standard. The materials used in this testing cannot be reused after the welding operation. This test costs a lot of money and materials. So, the purpose of introducing the computer-based testing environment is to reduce the cost of the materials and to aware user regarding the safety measures to avoid any accident when working in real job. Moreover, the welding inspector can get a better result by observing the welder as well as the date provided by the computer. This training does not consume much preparation time and the test can be quickly prepared for another welder. Research suggests that "Virtual reality technology has emerged as a simulation technology with a great potential of supporting design and training activities. This computer-based training, such as virtual reality, is one of the newer welding training aids. Virtual reality technology has emerged as a simulation technology with a great potential of supporting design and training activities. The benefits of virtual reality in virtual prototyping of assembly and maintenance verification have been demonstrated during a user survey that was performed at the premises of BMW by a representative group of key users. The work indicated that the use of virtual reality for virtual prototyping in the near future would play an important role in the automotive and probably in other industries" (Mavrikios et al., 2006, p. 294).

Computer-based virtual reality (VR) training has generated interest because they have the potential to reduce training costs. However, cost savings are only beneficial if the result is a competent welder who is trained in a timely manner. Some studies have shown that the use of VR technology leads to the reduction of learning time and the transfer of skills. Also, the use of VR technologies in training is not significantly different from real-world training. In this training, different software has been used to create a virtual welding scenario, such as SolidWorks, 3ds Max, Unity, and Visual Studio. This virtual scenario is later combined with the physical world that includes both real and computer-generated objects which are known as Mixed Reality (MR). This reality allows the welder to interact inside the virtual reality and perform the welding operation along with the proper guidance and instruction. Therefore, MR allows welders to work in a new environment (a combination of virtual and real words) for better training and to make them ready for real works.

2. Literature Review

The use of virtual reality (VR) based methods to support integrated human simulation for manual welding processes. Under this framework, a prototype demonstrator was developed, named 'the virtual welding environment', which provides functionality inside a virtual environment for immersive and interactive process execution. This environment's simulation features allow the user to configure, conduct, and verify the results of a welding operation. This environment shows promising potential to support process design and manual welding-related training procedures. Its aim was to support process experimentation concerning factors, which cannot be analytically described and therefore do not predetermined affect the process. Consequently, the focus was on the verification of subjective or random aspects of human involvement in relation to the welding process, the product, and the working environment. In terms of potential use, the virtual welding demonstrator incorporates features to help the design and testing of welding processes: the environment allows the user to conduct the welding process setup procedures, the process is conducted digitally in an immersive and interactive manner, and the system is currently operating on a Silicon Graphics ONYX2 Workstation with an Infinite Reality 2 Graphics Pipeline. The VR peripherals, which are used to enable immersive and interactive process execution within the virtual assembly environment, include an FS5 Virtual Research helmet, a Cyber Glove with Cyber Touch and Gesture Plus Virtual Technologies 18 sensor, a 3D Mouse Section, and a Polhemus Fastrack tracking device. With the use of Pro/Engineer V.20.verification of process characteristics, the virtual welding system was modeled. A number of specific functions were also introduced to support the activities of the interactive user in the virtual welding environment, including input evaluation functions, assembly function, process evaluation functions, welding seam creation function, and results' representation functions. This paper identified the idea and the functionality of a prototype demonstrator, the virtual welding demonstrator, which can be used for welding processes as design verification and training tool. Based on simulation techniques for virtual reality, this environment allows for immersive and interactive performance in the process. Within the virtual welding demonstrator, the user can set up and conduct a welding MIG/MAG process, providing quantitative environment input in real-time that provides support and overview of the process performed (Mavrikios et al., 2006).

In late 2005, ASSE's Northeastern Illinois Chapter and AIHA's Chicago Local Section jointly presented a seminar on welding safety and health. SH&E practitioners have provided contradictory reports about welding hazards over the last few years, although employees exposed to welding fumes have a rise in mass tort litigation among them. The seminar also looked at the new advances in handling welding risks. Health hazards brought by welding hazards are inevitable. Several illness have been linked to the contaminants that make up welding particles, vapors, and fumes. Short-term disease widely reported among welders involves irritation of the respiratory tract and fever from metal fume. On long term over, however, exposure can cause siderosis or Welder's Lung characterized by iron pigmentation in the lungs leading to further exacerbation of the symptoms of other pulmonary diseases such as silicosis, asbestosis and emphysema. Other possible harmful health effects associated with welding include asthma, distorted posture, hearing loss, heat stress, lowered immunity, repetitive stress and reproductive problems, welder's flash. Welders may also suffer from photo keratoconjunctivitis, also known as "welder's flash." Acute corneal inflammation is caused by overexposure to ultraviolet light, which happens most commonly when a welder directly views an arc. For welding safety measures, SH&E professionals play a vital role in shielding welders from the many hazards that they encounter in their work. The seminar speakers discussed practical methods for evaluating and controlling welding hazards. Welders regularly work with equipment that poses numerous safety hazards, according to Petitti. Unless handled and stored properly, devices such as gas cylinders, drums, and containers may combust or explode. Other tools such as manifolds, hoses, torches, manual electrode holders, and cables can trigger fires or electrocution if they are misused or defective. Welders must also exercise caution when working in confined spaces or in areas that contain potential fire hazards. Petitti emphasized the importance of PPE for welders. Welders should wear a shield or helmet with a filtered lens that is of the correct hue to avoid damage to the eyes and ears. Frey noted that one recent breakthrough, the auto-darkening shade, has greatly advanced eye safety for welders. This shade automatically responds to ultraviolet and infrared light so that welders do not need to change shades depending on the type of welding work performed or electrode used. This shade also increases welding accuracy, quality, and productivity. Petitti recommended that welders follow existing practices for the safe use, transportation, and storage of welding equipment, particularly compressed gas cylinders. To open a cylinder valve securely, the spindle should always be opened slowly and by not more than one and a half turns. Regulators must also be used in conjunction with compressed gases to minimize pressure in the system. On the basis of the information provided, further work needs to be carried out to confirm the direct health effects of exposure to welding fume, particularly when those fumes contain manganese. At the same time, welders, as well as SH&E practitioners, will continue to follow proven procedures to protect against the health risks associated with welding (Safety et al., 2006).

The evaluation of the health and safety aspects of welding can be extremely complex because of the large number of disciplines involved. The quite recent knowledge of court cases in the USA related to welders presenting Parkinson's disease and lung cancer and associating it with their profession has led to in-depth studies on the cause-effect of manual arc welding on these conditions. Major investments are being made in Europe with the goal of researching these problems and clarifying the real effect on human health of these factors and the ways and means to prevent them. ECONWELD Project, co-financed by the European Commission under the FP6 Programme, which lasted from 2005-09 and produced very promising results, not only in the field of ergonomics but also in terms of welding costs and fume reduction. Similar initiatives should be pursued by European companies to find a solid foundation for implementing new, ergonomic approaches within workspaces. A project in which a new design has been introduced for a self-aspiring torch and a welding mask and a program to guide professionals is being created to determine the fumes emissions of a given welding technique. Bad ergonomics and the harmful effect of electromagnetic field on Welder's health has also been discussed. The European Federation for Welding, Joining and Cutting (EWF), by virtue of its unique international expertise, has developed a high integrity and specialized certification system to assure companies' compliance with EN ISO 3834 and with the EWF requirements for the Environmental and Health and Safety Management. This system is known as the EWF Manufacturer Certification System (EWF MCS). The primary aim of MCS certification is to ensure that manufacturers are competent and have sufficient control over the special welding process so that consumers and others can be assured that the welded products they produce will comply with the regulatory and/or contractual requirements as relates to quality and environment health and safety. Health and safety in welding are very important issues that need to be addressed worldwide. Europe is strongly investing in clarifying the long-term impact of welding technologies on the human body (Quintino et al., 2009).

Training in the welding industry is a critical and often costly endeavor; this study examines the training potential, team learning, material consumption, and cost implications of using integrated virtual reality technology as a major part of welder training. In this study, 22 participants were trained using one of two separate methods (traditional training (TT) and virtual reality integrated training (VRI)). The results demonstrated that students trained using 50% virtual reality had training outcomes that surpassed those of traditionally trained students across four distinctive weld qualifications (2F, 1G, 3F, 3G). In addition, the

VRI group demonstrated significantly higher levels of team interaction, which led to increased team-based learning. Lastly, the material cost impact of the VRI group was significantly less than that of the TT group, even though both schools operated over a full two-week period. Prior to conducting this investigation, the authors hypothesized the VR integrated training would result in superior training outcomes when compared to traditional methods, the use of a state-of-the-art VR system would lead to increased levels of team interaction and learning, and weld training conducted with VR integrated technology would be significantly less expensive than training conducted using traditional means. There were 22 participants in total (21 male and 1 female). Participants were randomly assigned to one of two groups. Group one (VRI) subjects were trained with 50% VR + 50% traditional training, whereas group two (TT) subjects were trained using only the traditional training system. The primary independent variable in this experiment was training type at two levels, representing the type of interface tested: Traditional Weld Training (TT) and 50% Virtual Reality Training (VRI). There were five major dependent measures in this investigation: percentage transfer, training effectiveness ratio (TER), team learning, material consumption, and cost-effectiveness. Both TT and VRI groups were given the same overall training time opportunity for each weld type. The major difference between traditional training and VR integrated training was in the training system itself. Participants in the VRI group spent only 50% of their time training (lectures and practical lab training) under the direction of an AWS CWI for each weld type. The remaining 50% of their time was spent training on the VR system. In training potential, in terms of qualification rate and training time for the 2F position, the VRI group was found to have a 22.2% positive transfer and a TER of 1.81 when compared to the TT group. For the 1G level, in terms of qualification rate and training time. It was found that the VRI group has a positive transfer of 66.7% and a TER of 5.68 when compared to the TT group. In terms of qualification rate and training time for the 3F position. The VRI group was found to have a 66.7% positive transfer and a TER of 5.68 when compared to the TT group. For the 3G level, in terms of qualification rate and training time. The VRI group was found to have a 60% positive transfer and a TER of 5.17 when compared to the TT group. Students in the VRI viewed their team members as sources of knowledge to a greater extent than did students in the TT group. The material consumption in the real world was less to the VRI group than those of TT, whereas in virtual world stock material consumption, the VRI group used a significantly large amount. In the real world cost implications, VRI group was much cheaper than TT. The findings of this study clearly illustrate the direct benefits of using integrated training in the welding domain with virtual reality. The VRI community students showed significantly superior results in training relative to their traditionally trained counterparts. The factor associated with this outcome is the significantly higher levels of team learning and interaction among VRI students and the significantly greater amount of welds performed by VRI students in the VR environment. Aside from encouraging greater learning performance, the use of integrated VR training greatly decreases the associated cost of training (Stone et al., 2011).

The study emphasizes on the health aspects of welders, which will help to create awareness about the importance of improved working methods and safe industrial environments. A number of different epidemiological studies have proved the relationship between welding and serious health disorders, namely malignancies. Exposure of welding fumes has caused several diseases, including lung cancer. It is found that metal workers have a significantly increased risk of death from lung cancer (proportional mortality ratios PMR = 134). Studies have shown the health effects on welders using different models and the account of the effect of welding process on the health of the workers through the study on analysis of blood and urine for different parameters like micronucleus test, comet assay, true metal analysis such as lead levels, chromium, cadmium and nickel levels, manganese levels, cytogenetic analysis, chromosomal aberrations and sister chromatid exchanges. These studies give evidence about the serious occupational risk posed to the welders, which should be minimized using personal protection equipment. Various studies have shown increased DNA damage in welders that may eventually lead to serious health problems, including careers of the welders. The article mentions the only way to diminish the exposure of welders is by using protection equipment, including face masks, hand gloves and light filters along with well-ventilated and airy working environments. Noise and radiation levels should also be minimized. Carry-home exposure should also be reduced. Conclusively, there is a great need to check the health of welders on a regular basis working in different iron-based industries to reduce the occupational health risk factor (Chadha & Singh, 2013).

The use of dexterity to suggest the potential success of the starting welders in selecting participants for training programs on welding. With a high demand for welders, effective welding training programs are imperative but can be time-consuming. One of the challenges that training programs face is the time needed to train qualified welders. Many occupational fields have sought to predict the potential success of a student by evaluating their dexterous ability before accepting them to a training program. This study used the Complete Minnesota Dexterity Test (CMDT) to examine the dexterity of participants during a welding workout program. At the end of the training program, participants performed weld test which was supervised by a certified welding instructor (CWI) who inspected each weld visually. When evaluating participant dexterity on the first day of training, it can be found that 78.3% of the participants had the low dexterous ability with the positioning and turning tests. However, on the displacement test on the first day of training 34.8% of participants exuded a very high degree of dexterity. Participant flexibility has been isolated for the two-week training programs. A general improvement in dexterous ability can be seen in all three forms of tests performed in the 50/50 virtual and conventional forms of training. All three dexterity tests showed statistically relevant correlations to the participants' visual pass/fail rates for simply shielded metal arc welds (SMAW). It can be concluded that dexterity can predict the future output of the starting welders, which complete basic SMAW welds (Preston Byrd et al., 2019).

3. Problem Description

It is assumed that welding existed in some form as far as the Iron Age and the Bronze Age. There is evidence that the Egyptians learned to weld iron together and also found small gold boxes that were welded from over 2,000 years ago with lap joint strain. The type of welding then prevalent and found in the Middle Ages was, however, a rather rudimentary form of welding, which usually involved simply hammering two pieces of metal together under heat until they joined. Some of the earliest inroads toward traditional welding came about as early as 1800. Thereafter, welding processes advanced very fast. People have been developing more and more efficient techniques for accurate, fast, and successful welding since the 19^{th} century (Reed, B., 2019). Manual welding is one of the best job opportunities all over the world. Many companies, construction firms, and manufacturers hire welders. But, those employers are not arbitrarily recruiting. Each organization has its own requirements and system relating to the welding process. So welders need to master the welding skills to fit on the program. The talent does not come in one single day. It needs a lot of training, commitment, and time. It is only through practice and practice that the thing which helps to master the welding skill. Trainers have to pay the costs for the supplies, equipment, and tools, etc., to practice welding.

Welding is among risky occupations and is subject to many hazards for the related jobs. The detention and denial of these threats play an important role in their health and healthy environment. On the one side, welding is the connection of metal parts with the assistance of welding metal filler and heat or pressure. In other words, the welding process is hazardous, laborious, and detrimental to the profession. Burning of skin, flickering eye burns, and fire are some of the most serious and severe risks. Fumes are solid particles that come from the consumables of welding, the base metal, and any coatings on the base metal. Obviously, the sun is the primary cause of human exposure to UV radiation. Though the sun is the most significant source of exposure to electromagnetic radiation for all, the sensitivity of welders to ultraviolet radiation is due solely to the welding procedures (Zamanian et al., 2015). Also, there will be the use of electricity when talking about welding operations. If people who use, contact or supervise the use of these processes do not fully appreciate that their improper use can result in loss of life and property by poisoning, fire, explosion or electric shock. The electrode and work circuit is electrically live whenever the output is on. The input power circuit and internal machine circuits are also live when power is on. Carelessness in these terms may cause injury or severe damage to the body.

The study primarily focused on reducing the cost and minimize the health hazards during welding training. The Mixed Reality method is used to train the welders with reduction of material costs and minimizing the health risks. The proposed methodology and step-by-step process of the method will be described in the next section of this paper.

4. Methodology

The proposed model of this paper is to train welders in a Mixed Reality which is the product of combining the physical world with the digital world. Mixed reality is the next step of contact between humans, machines, and the world and explores possibilities that previously were confined to our imaginations. Advances in computer vision, graphics processing power, display technology, and input systems make this possible. It also includes environmental input, spatial sound, and location. The connection between human and computer input has been well explored over the past several decades. It also has a widely researched discipline known as human interface computers or HCI. Human feedback occurs through a number of means, including keyboards, mice, contact, ink, voice, and even Kinect skeletal tracking. Environmental input measures such aspects as the position of a person in the world (e.g., head tracking), surfaces and boundaries (e.g., spatial mapping and perception of the scene), ambient lighting, environmental sound, object recognition, and place. Now, integrating all three: computer processing, human input, and environmental feedback set the ability to construct true perceptions of mixed reality. In the physical world, boundaries will affect application interactions in the digital environment, such as gameplay. Experiences cannot merge between physical and digital realities without environmental input which is presented in Fig.1 (BrandonBray).

It is a challenging task to achieve high standards of welding because welders need to be extremely skilled and trained. These requirements can be fulfilled only through years of experience. So, the main point of implementing the mixed reality is to give confidence and a better understanding of the welding. There are some methods that need to be followed to train the welders using mixed reality. A step-by-step procedure, including diagrams, used to create this new model can be seen in the next section. The proposed method started with the first step, i.e., to study the welding workshop setup in detail which is required to create in a virtual environment so that welders can experience the real workshop while training. The setup includes materials, equipment, and tools that are required for the welding operation. All the equipment, materials, tools, and protective wear that are available in the real workshop need to be created in the virtual scenario for a better experience. The next step is to find the Computer-Aided Design (CAD) model of the required materials. These models can be downloaded from grabcad.com, which is an online website where numerous CAD are available, or the required CAD model can be designed with the help of software known as SolidWorks. It is the software that enables designers to quickly transform new ideas into great products. SolidWorks is a highly efficient 3D CAD development platform with integrated analytical tools and automation design to help enhance physical behaviors such as kinematics, friction, tension, deflection, vibration, temperature, or fluid flow to match all design types. Then, these CAD models are exported to 3ds Max, another software used for optimizing and editing the mesh. 3ds Max is a computer graphics software designed to construct 3D models, animations, and digital images. It is one of the most common programs in the computer graphics industry and is well-known for having a strong 3D artist's tool collection. It is well known for its unmatched speed and simplicity when it comes to modelling. Later, the file is exported into Filmbox (FBX) file format so that it can be imported to Unity where all the CAD files are brought together to create a workshop with animation.

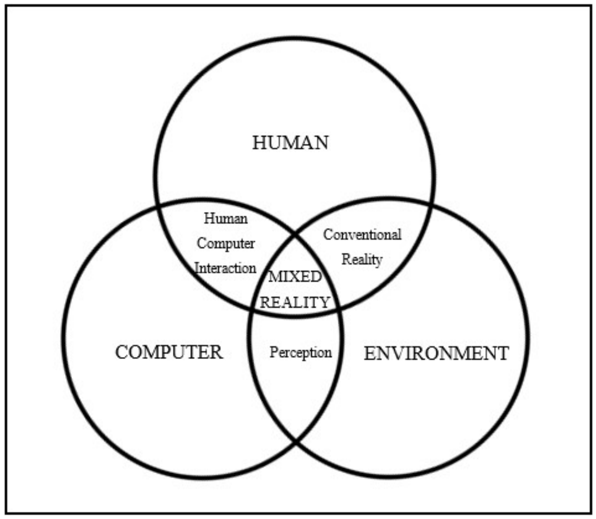


Fig. 1. The interference between computers, humans and environments.

Unity is the main software for improving gameplay. Unity is used to create 3D and 2D games of high quality, deploy them across desktop, VR, console. It is a motor of the cross-platform game which is mainly used for computer and mobile video games and simulations. The first-person controller in unity help to move inside around the virtual environment and also allow to grab a gun and perform welding. With this feature, the user can grab different tools required in welding. Unity has built-in support for writing scripts in Visual Studio Code as an external script editor on different operating software. These scripts help to run out virtual workshops. Also, the trainers can be assisted during the training with the help of voice or visual instructions, which is possible because of the unity program. The last step to complete the model is to merge the animated workshop with the real world to train the welders proficiently. In this case, the device name oculus rift comes handy. It is a virtual reality technology developed by Oculus VR. The Oculus is a head-mounted system that allows users to interact naturally with simulated 3D environments. This training scenario help to improve the hand on performance and also improve the knowledge of the welders. In this scenario, the welders need to perform two tests, plate welding, and pipe welding, for certification. When the welder starts the program, there will be tasks that need to be done during the training. Task 1 will be moved near to welding table 1, and grab a gun along with the voice instruction. Task 2 is to go near welding table 2 and perform a plate welding test. Task 3 is to perform pipe, which will be placed on the welding table 3. By reviewing their performance, the welding inspector will certify them.

5. Illustrative Example

An illustrative example of this process can be seen in this section. With the help of the software mentioned in the procedure, make the environment possible. First of all, the model is studied in detail to create a real welding station. Then, the required materials, tools, and equipment are created with the help of SolidWorks, which is illustrated in Fig. 2.

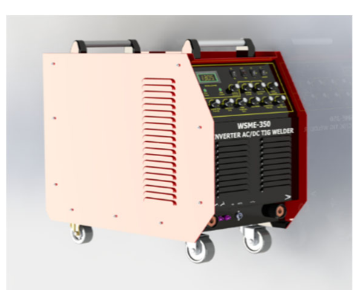


Fig. 2. Rendering in SolidWorks

After that, these CAD models are subjected in 3ds Max to optimize the model along with the mesh edition. Later, the model is exported to FBX file format because it is used to provide interoperability between digital content creation applications. This FBX file is imported in Unity to create the welding station, which is shown in Fig. 3.

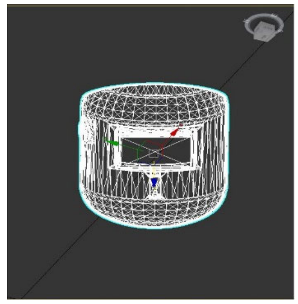
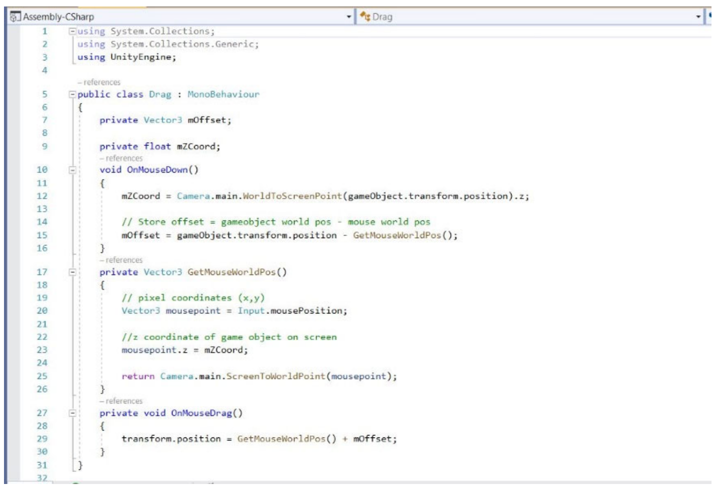


Fig. 3. Optimizing and editing the mesh of CAD model in 3ds Max.

Unity has built-in support known as Visual Studio Code, which allows writing the script so that different functions can be made possible. The script required to hold the gun is depicted in Fig. 4.



```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class Drag : MonoBehaviour
{
    private Vector3 mOffset;

    private float mZCoord;

    void OnMouseDown()
    {
        mZCoord = Camera.main.WorldToScreenPoint(gameObject.transform.position).z;

        // Store offset = gameobject world pos - mouse world pos
        mOffset = gameObject.transform.position - GetMouseWorldPos();
    }

    private Vector3 GetMouseWorldPos()
    {
        // pixel coordinates (x,y)
        Vector3 mousepoint = Input.mousePosition;

        //z coordinate of game object on screen
        mousepoint.z = mZCoord;

        return Camera.main.ScreenToWorldPoint(mousepoint);
    }

    private void OnMouseDrag()
    {
        transform.position = GetMouseWorldPos() + mOffset;
    }
}
```

Fig. 4. C# Sharp script for grabbing and moving objects in visual studio.

The welders can feel the ambiance of a virtual scenario with the help of a device known as oculus rift. The trackers help to manipulate inside the training, such as lifting and grabbing as per the direction of welders. The main aim of this training program is to train the welders and certified them by allowing them to perform the test. Welding certifications are generally a hands-on welder training examination performed by a qualified welding inspector who will decide if the individual or machine can produce sound quality welding according to the code or welding technique necessary for a job site or industry standard. The author examined the welding test in VR simulator have total participants of 49 males of varying ages. Additionally, all the study participants had completed a structured welding training program and were working as welders. They were either classified as experienced welders or trained inexperienced welders. Experienced welders were either listed as having at least ten years of experience in welding or as a qualified welder. Trained inexperienced welders were individuals who did not have more than a year of experience. It includes 18 experienced and 31 trained inexperienced welders. The data is presented in Table 1.

Table 1
Quality score by experience and weld type (Byrd et al., 2015)

	A	B	C	D	E	F	G
1	Experience and Weld Type	N	Range	Minimum	Maximum	Mean	SD
2							
3	Experienced 2F	18	30	70	100	86.33	7.88
4	Experienced 1G	18	30	70	100	84.89	8.24
5	Experienced 3F	18	17	72	89	82.5	4.43
6	Experienced 3G	18	41	49	90	77.39	10.57
7							
8	Trained inexperience 2F	31	38	61	99	78.94	9.05
9	Trained inexperience 1G	31	57	32	89	74.68	11.41
10	Trained inexperience 3F	31	38	52	90	71.97	9.1
11	Trained inexperience 3F	31	65	20	85	62.35	16.23

For the Shielded Metal Arc Welding (SMAW) test welds, the dependent variable was the quality score (2F, 1G, 3F, 3G). The two independent variables are participant skill level and weld style in order to increase the complexity as follows: 2F (horizontal fillet weld), 1G (flat groove weld), 3F (vertical fillet weld), and 3G (vertical groove weld). Participant performance was evaluated using a quality score generated by the VR simulator (Byrd et al., 2015).

6. Limitations and Complications

There are some limitations in this training through the training costs less and prevents the users from hazardous gases and fumes. The filler material increased the strength of welding, which is a limitation in mixed reality because the chemical composition of the filler material cannot be tested. The complications of this welding environment are it cannot replicate the real welding operation. However, it allows welders to practice and perfect their skills as a companion to hands-on. The welders may experience certain health issues such as nausea, anxiety, and eye strain.

7. Results and Conclusion

The performance of the welders in virtual reality training is examined, and the experienced welders outperformed the trained, inexperienced welders by an average of 10 quality points. Overall performance was highest among the experienced welder group with an average of 83, which was higher than the trained, inexperienced welder group by 12 quality points which is clearly shown in Fig. 5 and Fig. 6, respectively.

	A	B	C	D	E	F
1		2F	1G	3F	3G	Overall Average
2	diff	70.00	70.00	72.00	49.00	65.25
3	Q1	11.02	9.33	7.51	21.26	12.28
4	median	6.31	5.56	2.99	7.13	5.25
5	Q3	4.32	5.56	2.99	7.13	5.25
6	maximum	8.36	9.55	3.51	5.48	6.72
7						
8						
9	n	18.00	18.00	18.00	18.00	18.00
10	range	30.00	30.00	17.00	41.00	29.50
11						
12	minimum	70.00	70.00	72.00	49.00	65.25
13	Q1	81.02	79.33	79.51	70.26	77.53
14	median	87.32	84.89	82.50	77.39	82.78
15	Q3	91.64	90.45	85.49	84.52	88.03
16	maximum	100.00	100.00	89.00	90.00	94.75
17						
18	mean	86.33	84.89	82.50	77.39	82.78
19	sd	7.88	8.24	4.43	10.57	7.78

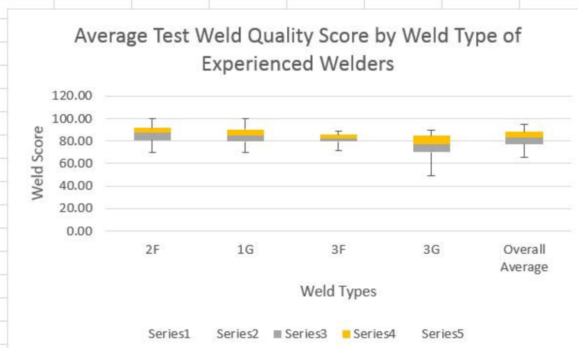


Fig. 5. Average SMAW test weld quality score by weld type of experienced welders

	A	B	C	D	E	F
1		2F	1G	3F	3G	Overall Average
2	diff	61.00	32.00	52.00	20.00	41.25
3	Q1	11.84	34.98	13.83	31.40	23.01
4	median	7.24	7.70	6.14	10.95	7.72
5	Q3	4.97	7.70	6.14	10.95	7.72
6	maximum	13.96	6.62	11.89	11.70	11.04
7						
8						
9	n	31.00	31.00	31.00	31.00	31.00
10	range	38.00	57.00	38.00	65.00	49.50
11						
12	minimum	61.00	32.00	52.00	20.00	41.25
13	Q1	72.84	66.98	65.83	51.40	64.26
14	median	80.08	74.68	71.97	62.35	71.99
15	Q3	85.04	82.38	78.11	73.30	79.71
16	maximum	99.00	89.00	90.00	85.00	90.75
17						
18	mean	78.94	74.68	71.97	62.35	71.99
19	sd	9.05	11.41	9.10	16.23	11.45

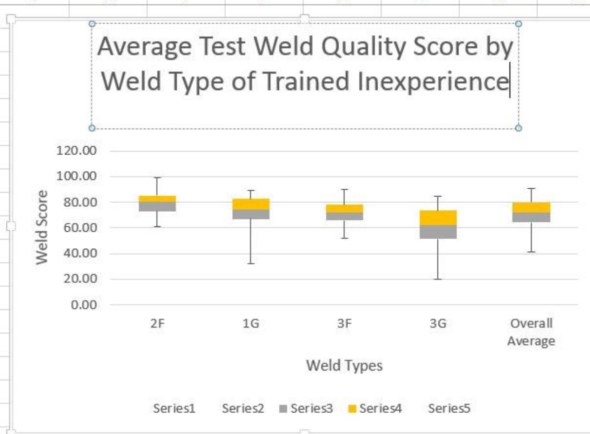


Fig. 6. Average SMAW test weld quality score by weld type of trained inexperienced welders.

In the fourth paragraph of the literature review, the training was assigned, and a test was conducted between virtual reality training and traditional weld training. Training potential is defined by both the percent transfer and the transfer effectiveness ratio (TER). As a result, virtual reality training has more positive transfer and high TER as compared to traditional weld training (Stone et al., 2011). Thus, the performance of the welders in learning welding takes less time than that of traditional ones. The development of the welding training scenario in mixed reality thus allows the user to omit the restriction of movement and grabbing. This study enables users to exploit within the virtual world with the help of trackers and cameras. Therefore, the welder can take the plate and position it on the welding table according to the welder's versatility. Furthermore, the welder can also walk along with the welding gun to another welding table to perform different operations like pipe welding. With this feature available, welder's performance is enhanced dramatically. This training scenario also includes voice instruction, and visual instruction is also possible with the help of a panel inside the scenario. So, it displays a warning message every time the welder performs out of instruction. In this way, the welder knows the error and performs well in the future. This method is much more convenient and less expensive than traditional training. Also, when working in mixed reality, gasses, smoke, dust, and exposure to UV light and electric shock are absent. Thus, the safety of the welder is not compromised and is fully protected from the hazardous factors mentioned in the problem description. Also, this approach is environmentally friendly. Future research activities will include the test to find the occurrence of welding defects in mixed reality. It can also be used in different fields by implementing the standards of respective fields.

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