HUMAN-COMPUTER INTERACTION DESIGN FOR VIRTUAL REALITY METAL ARC WELDING USING EMERGING TECHNOLOGIES

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Abstract: Virtual Reality Metal Arc Welding (VRMAW) is a three – dimensional computer programmed environment that explores to interact for an illusion of seeing, hearing, touching and feel of the welding process. VRMAW uses Human-Computer Interaction (HCI) design with the usage of emerging technologies such as Virtual Reality and Augmented Reality to experience the immersive virtual environment usually difficult in conventional environment. VRMAW is a unique and innovative welding process in virtual environment using sensors, virtual reality glass, virtual reality controller, smartphone, Computer Aided Design (CAD) tools, C-sharp, Virtual reality Modelling Language (VRML) and Unity 3D to an immersive environment of welding and feel of real metal arc welding. This paper explains five phases of VRMAW i.e. concept phase, modelling phase, gaming phase, integration phase and analysis phase. The research work uses NASAs Technology Readiness Level (TRL) and Manufacturing Readiness Level (MRL) methods to assess the maturity of a technology and manufacturing process that assist engineers/designers/researchers in managing risks, communicating development progress and specifying deliverables. This research and innovation work concludes a first of its kind welding product uses state-of-the-art technology in welding which promotes digital technology to train the unskilled in metal arc welding with an advantage of economic, clean and green technology.

Index Terms – Human Computer Interaction, VRMAW, TRL, MRL, Unity 3D

I. INTRODUCTION TO HUMAN COMPUTER INTERACTION

Human-computer interaction of interactive computing systems covers four specific areas. The first specific area is design of interactive computing systems that involves developing interactive products that are easy and effective to use. The second specific area is implementation of interactive computing systems that provides the capability of harnessing technology and ideas. The third specific area is evaluation of interactive computing systems for collecting data of user product systematically for a particular task in virtual environment. The fourth specific area is the study of surrounding phenomenon for communicating between user and the machine. This research work focuses only on design of human computer interaction with building and evaluating the prototype of VRMAW using smart phone application. Interaction design as properties of a system and interaction design as the process of creating a system are the two distinct categories of design of human-computer interaction [1-8]. The first category is concerned with the way users interact with the computer by the exploration of interaction design in its material form and the second category is concerned with the exploration of ways the material form are created. Mobility and immersion are often described as reality – virtuality linear continuum. Computer displays are capable of delivering an inclusive, extensive, surrounding, and vivid illusion of reality to the senses of a user is the property of immersion. State of being able to move or be moved quickly from place to other place is the property of mobility is the property of a user.

Virtual Reality (VR) is the use of computers and human-computer interfaces to create the effect of a three-dimensional world containing interactive objects with a strong sense of three-dimensional presence. VR environment aims to provide participants a perception of presence with two aspects namely immersion and intuitive interaction. Based on this concept, user explores to rapid technology development in the field of VR [9-18]. Collaborative Virtual Reality (CVR) provides interaction among the smart phone and the virtual reality controller. VR facilitates a high level of immersion into virtual space compared to desktop computer systems. VR systems covers a large proportion of the user’s visual field of view and interaction devices sensing the user’s physical movements. VR allows the user to step into expensive, dangerous or even impossible environment to experience in the real world cases. For example, the simulations of complex industrial installations, construction of new building, visualizations of complex objects, invisible molecules of matter and direction of airflow.

Smart phone systems are the systems running on small, lightweight, easily moveable, wireless and self-contained computing devices with input and output capabilities. Smart phone systems facilitate a high level of mobility in physical space compared to personal computers. Smart phone systems allow the user to access digital information while moving through physical space. Smart phone systems provides gyroscopic and bluetooth sensors for interaction between the one devices to another device. Figure 1 shows the reality-virtuality linear continuum.

II. DESIGN OF VIRTUAL REALITY METAL ARC WELDING

The VRMAW is divided into five phases namely concept phase, modelling phase, gaming phase, integration phase and analysis phase. The concept phase of VRMAW is collecting the relevant data from the past literature and idea to achieve the end product.
The modelling phase involves 3D modelling creation of metal arc welding platform using Computer Aided Design (CAD) tools. The gaming phase is to import the CAD model (four welded joints design (Butt, Lap, Corner and T-joints), human hand, helmet, electrode holder and an electrode models) in Unity 3D engine to visualize the welding platform in virtual environment. The interaction phase is to obtain human-computer interaction design process by using C-sharp programming language. The analysis phase, determines the welding speed and welding time with graph and report. Figure 2 the flowchart of the five phases of virtual reality metal arc welding.

Figure 2. Flowchart of the five phases of virtual reality metal arc welding.

2.1 Concept of VRMAW

Usually the trainers in under-graduate universities and industries are not expertise that decreased the count of skilled welders. It impacts the training to under-graduate students, manufacturing and several construction industries. This is because of high cost in training, material and maintenance of equipment. The complexity in manual metal arc welding is the trajectory of the geometry and path of welding which becomes difficult to weld and can be done either by a skilled welder or a robot. This complexity arise is reduced by implementing the concept of virtual reality in metal arc welding with the consideration of basic principles of welding (TRL 1 and MRL 1). Learning and practicing metal arc welding can be made easy, clean, green, economic and fast with the help of virtual reality metal arc welding.

2.2 3D Modelling of VRMAW

The 3D modelling of VRMAW consists of modelling of electrode holder, helmet, workpieces and a welding table which has been created using 3DS Max CAD tool. The modelling of these models where made based on the reverse engineering. The models are created in such a way that it must resembles same as a realistic model in immersive virtual environment. Figure 3 shows the model of electrode holder where the dimensions are considered by reverse engineering of welding electrode holder. Figure 4 shows the model of helmet and Figure 5 shows the model of four welded joint workpieces (Lap, Corner, T joint and Butt joints). Figure 6 shows welding table 3D model.
Figure 3. Electrode Holder Model

Figure 4. Helmet Model

Figure 5. Welded Joints Models
III. DEVELOPMENT OF VIRTUAL REALITY METAL ARC WELDING

In the development of VRMAW, usage of the right CAD tool is very much essential to convert CAD model of welding platform to virtual reality welding platform model. The great challenge is to obtain the interactivity between CAD welding model and virtual reality tools for the user to experience the 3D immersive environment by feeling of “being in” and “looking at” a virtual environment. Virtual reality technology concept for metal arc welding is formulated (TRL2). On the basis of this concept, virtual reality displays are divided into categories of full immersive displays and partial immersive displays, but the limitations to my research is focused only on full immersive displays for virtual welding application such as head-mounted displays and virtual reality controllers. Figure 7 shows the CAD model and virtual reality model of welding platform in virtual environment.

3.1 Interaction between the virtual environment and sensors

The interaction development process of virtual metal arc welding system is to develop an application to interact between the virtual environment and virtual reality controllers with gyroscopic and bluetooth sensors using an android smartphone information system and Unity 3D software application (MRL 2). The interaction in this research work is divided into three categories namely orientating, moving and acting of a welding. Orientating addresses the need for looking around in a virtual environment, moving addresses the need to move about in a virtual environment and acting addresses the need for selecting, moving, rotating and transforming virtual objects. Interaction techniques suitable for supporting orientating, moving and acting in virtual reality depend on the display’s available field of view. Thus partial immersive displays require interaction techniques supporting a relatively stationary user while interaction techniques for full immersive displays must consider a more freely moving user [19-22]. In this VRMAW process, a field study provided a data about a mobile work activity, an object-oriented method informed interaction design and evaluated in a high-fidelity simulation of the real use context that showcases the experimental proof of interactivity concept (TRL 3). The analysis report of the welding is generated with the real time weld speed and weld time of the weld bead that enhances the corroboration of virtual reality technology in metal arc welding (TRL 4). Figure 8 shows the flow process of VRMAW from the user username to the user welding report.
3.3 Scripting for Interaction of VRMAW

The script for selection of welding models, helmet, electrode holder, metal arc generation, sound and analysis are generated using C-sharp programming language. The following showcases the scripting of welding:

```csharp
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
namespace virtualWelding
{
    class virtualWelding_cl
    {
        public static string[] States = { "Fire1", "CloseToTable", "Welding", "Sparks"};
        public static string CurrentState
        {
            get;
            private set;
        }
        void Update()
        {
            if (Controls.CurrentState == "CloseToTable" && Input.GetButtonDown ("Fire1"))
            {
                Sparks.SetActive(true);
                welding = true;
                Controls.SwitchToWelding();
                Debug.Log(Controls.CurrentState);
                source.Play();
                hm.ToggleView();
            }
        }
    }
}
```

3.4 Innovation chain of VRMAW

Technology Readiness Level (TRL) is a method to estimate the technology maturity of critical technology elements of a program during the process. Manufacturing Readiness Level (MRL) is a measure developed to assess the maturity of manufacturing readiness to minimize the space between opportunity discovery (Idea) to product development which is termed as valley of death.

(a) Enter the user name; (b) Select the type of welding; (c) Virtual environment before welding; (d) Virtual environment after welding; (e) Select analyise for welding analysis of two parameters – weld speed and time; (f) A graph of weld speed vs time.

Figure 8. Flow process of VRMAW from entering the username to the user welding report.
In this research work, TRL 1 to TRL 4 and MRL 1 to MRL 2 is achieved. Basic principles of virtual reality concept is observed and studied (TRL 1), technology concept of virtual reality in welding such as immersion, interaction between the virtual environment and sensors using C sharp scripting language is formulated (TRL 2), simulation of virtual reality metal arc welding with the immersive display and audio feel is generated that proves the experimental proof for the interactivity concept (TRL 3). The above three TRLs enhances the knowledge development in academic level. With the collaboration of virtual reality softwares such as Unity 3D and Microsoft Visual Basic Studio initiation of technology development i.e. TRL 4 is achieved. As this research work is the part of virtual manufacturing, concept of virtual reality metal arc welding is proposed i.e. MRL 1 is accomplished and virtual welding mobile application is achieved for the demonstration of four welded joints with the weld speed and weld time report i.e. MRL 2 is achieved successfully. Figure 10 shows the usage of TRL and MRL in VRMAW.
Human-Computer Interaction design showcases the linear continuum between the reality and virtuality. This paper demonstrates the unique and innovative virtual reality metal arc welding process using emerging technologies from concept to the end product application. The three dimensional models of electrode, helmet, welding joints, table and human hand are designed in CAD tool. An android smartphone application of VRMAW is developed using codes generated in C-sharp programming language from adding of username to outcome of welding. The virtual reality controllers are used to move, orient and feel the welding process.

The practice of TRL and MRL is made to overcome the lack of an appropriate risk management and to cope up with the complex emerging technology development, advanced manufacturing technology and academic innovation. An attempt is made to achieve upto TRL 4 and MRL 2 in emerging technology development and virtual manufacturing respectively. The effective use of above technologies in VRMAW promotes to train the unskilled in metal arc welding by reducing the overall cost of training (material, power, equipment, floor area, etc.), minimize the risk, improves the understanding of welding concept clearly and initiates green training technology.

REFERENCES