Visualization of Virtual Weld Beads

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Abstract

In this paper, we present a visualization method of weld beads for a welding training under virtual environments. To represent virtual beads, a bead shape is defined according to the datasets which consist of bead width, height, angle, penetration acquired from real welding operations. A curve equation of bead's sectional shape is mathematical modeled, and a height map is generated according to this numerical equation, which is used for generating the bead's mesh data using its height information. Finally, virtual weld beads are visualized in real-time according to the accurately simulated results from user's input motion.

CR Categories: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities

Keywords: Virtual reality, Visualization, Welding, Bead, Training

1 Introduction

In virtual training systems for reducing training time and costs, it is necessary to achieve accurate simulation and realistic representation to provide the same effect of real training environments [Konieczny et al. 2008]. Virtual welding training also must provide visualization of welding parameters based on real environments such as beads, base metals, spark, arc, smoke, and so on. Specially, visualization of weld beads, which are a weld deposit produced by welding processes, is an extremely important factor in welding training systems. Weld beads have diffent characteristics and shapes in terms of width, height, angle, and penetration depth, where these output values are decided from input parameters such as electric current, voltage, speed of the welding torch moving, orientation of the torch, and the distance between base metals and the torch.

In this paper, we propose a new visualization method for representing for virtual beads using a mesh and a height map, which is based on the numerical calculation of sectional shapes of the bead. The numerical shape model is derived from collected real bead data such as bead width, height, angle, and penetration. Both the mesh and the height map, which were gathered from real experiments, are used to express a graphical object with characteristics of real bead's shape.

2 Related Work

In recent years, many virtual welding training simulators and assistant platforms have been proposed to increase technical skills
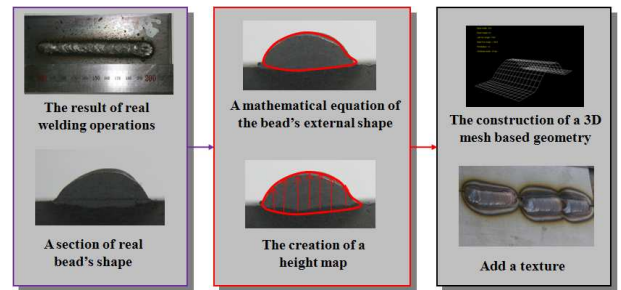

Figure 1: *The process of expressing virtual beads consists of constructing datasets based on real operations, deriving numerical expression of bead shape, and visualizing virtual beads with mesh and texture data.*

of welding workers. Choquet proposed a virtual welding simulator with which trainees can exercise for improving their skills and diagnose the results using 3D-glasses attached inside a welding helmet and a torch interface [Choquet 2008]. Fast et al. developed a training system which includes head-mounted display (HMD), haptic device, and a tracking system [Fast et al. 2004]. This system used neural network for mapping samples of measured bead's parameters (e.g. bead size, weld penetration). CSWAVE implemented a workbench based training platform for teaching a variety of welding exercises and analyzing trainee's progress (http://www.cswave.us).

Aiteanu et al. proposed an augmented reality based welding helmet to assist the real welding process by augmenting the visual information such as welding parameters, gun torch inclination, assembly information, and documentation [Aiteanu et al. 2003].

However, because these studies visualized beads with simple three-dimensional (3D) models, which do not include precise height information, there is no detailed expression of appearance of beads based on real environments such as the creation of a perfect copy of real beads.

3 The Expression of Virtual Beads

Figure 1 shows the process of expressing virtual beads which can apply to all base metals. Virtual beads take the input from the mesh data and texture images related to height information which is estimated by a section of real bead's shape. First, we perform real welding operations with different welding parameters (e.g., current, voltage, torch speed, torch angle, and torch distance) and collect sectional shape data of the results of real beads. Second, we define and construct a mathematical equation of the bead's external shape (e.g., bead width, height, angle, penetration) according to the collected data. According to this mathematical model, the height map is constructed which includes convex parts from the surface of the material (e.g. base metals). Then, a 3D mesh based geometry is constructed by elevation data of the height map in real time. Finally, a texture is added to the virtual bead geometry to make them look similar to real beads.

Figure 2 shows a section of a real bead and elements for making a bead's equation. We measured the bead's width, the bead height,

and the penetration depth from the bead's sectional surface. We also measured left and right tow angles that are the outside angle between base metals and tangent line of the bead.
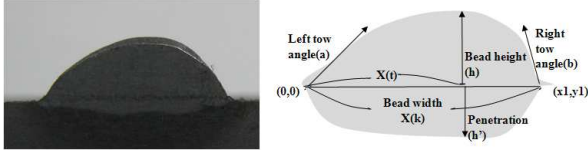

Figure 2: *A section of a real bead (left) and elements of the bead shape (right)*

The curve equations of beads shape, which consists of two quadratic equations with the second degree and have an axis of symmetry at the highest point $((X(t)),h)$, are defined as

$$F_L(x) = M_L * (x - X(t))^2 + h \qquad (1)$$

$$F_R(x) = M_R * (x - X(t))^2 + h \qquad (2)$$

where M_L and M_R are slopes of the tangent lines. $X(t)$ is a X value at the highest point of bead's surface, and h is the bead height at $X(t)$. The variable M_L is represented by

$$(x, F_L(x)) = (0,0), M_L = -h/((X(t))^2 \qquad (3)$$

And the variable $X(t)$ is represented by

$$X(t) = 2h/(tan(\pi - a)) \qquad (4)$$

This is derived from assuming that the value of the differential equation is equal to the slope of tangent line.

$$F'_L(x) = 2 * M_L * (x - X(t)) \qquad (5)$$

$$x = 0, F'_L(x) = -2 * M_L * X(t) = (tan(\pi - a)) \qquad (6)$$

$$-2 * (-h/(X(t))^2) * (X(t)) = (tan(\pi - a)) \qquad (7)$$

The variable M_R of the right curve equation is represented by

$$x = x1, -2 * M_R * (x1 - X(t)) = -(tan(\pi - b)) \qquad (8)$$

$$M_R = (tan(\pi - b))/(2 * (x1 - X(t)) \qquad (9)$$

4 Implementation

Figure 3 shows an example of visualization of a virtual bead including the height map and mesh data of the virtual bead. To build datasets from the results of real welding processes, we used a auto-welding carriage which performs welding with established welding parameters, and used a steel cutter to investigate the sections of the real beads. To visualize virtual beads, we also applied mesh generation and movement using the height map which consists of sampled height values from bead's curve equations of the shape of bead section. The virtual bead is represented in real time by reading user's mouse movement, and height map of the bead is visualized as color values.

Figure 4 shows the initial version of our virtual environment for virtual weld training. The environment not only includes realistic representation of the virtual bead, but also a base metal, a welding torch, a welding machine, and a shielding gas cylinder. As a development platform, we used VIRTOOLS to render virtual beads and Microsoft Office Excel to construct datasets. The system runs on a Microsoft Windows XP operating system.
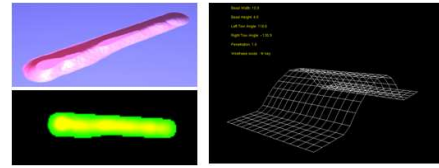

Figure 3: *Visualization of a virtual bead using the height map of the bead (left), and mesh information of the bead (right)*
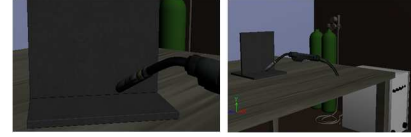

Figure 4: *The initial prototype of virtual environments for welding training*

5 Conclusions

In this paper we proposed a visual representation of weld beads for virtual training which provides accurate approximation of real beads to overcome the drawbacks of previous works. Using mathematical curve equations and the height map, we constructed visualization method of virtual beads to show the bead shape according to position and orientation of the torch. Therefore, the proposed method allows trainees to accurately and effectively practice with the simulated results under virtual training environments.

In our future work, we will represent the penetration depth of weld beads accroding to the collected data and various shielding gases. And, we will make verification of the visual results of our method for more accurate representation, using questionnaire results from the experts. Additionally, we will also work towards the development of a welding training system which includes trainee's real-time interaction, evaluation of welding results, and a virtual training hardware platform.

Acknowledgements

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