WireSketch: Bimanual Interactions for 3D Curve Networks in VR

Sang-Hyun Lee
Department of Industrial Design, KAIST
sang-hyun.lee@kaist.ac.kr

Taegyu Jin
Department of Industrial Design, KAIST
taegyu.jin@kaist.ac.kr

Joon Hyub Lee
Department of Industrial Design, KAIST
joonhyub.lee@kaist.ac.kr

Seok-Hyung Bae
Department of Industrial Design, KAIST
seokhyung.bae@kaist.ac.kr

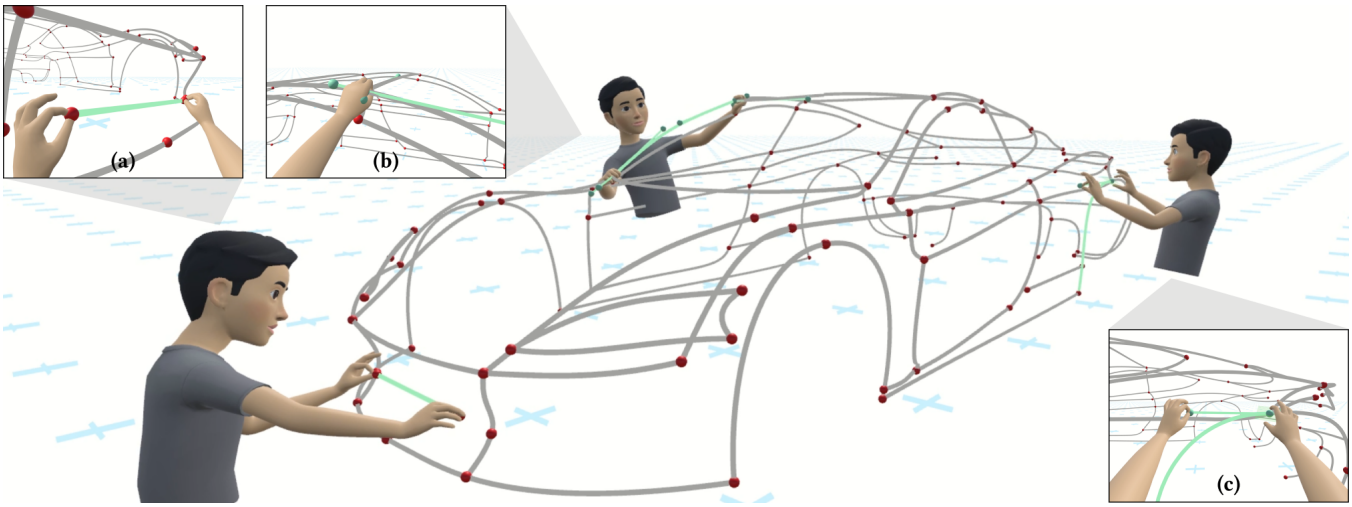

Figure 1: WireSketch is a 3D curve network authoring system that allows users to create 3D curves quickly and easily with bare hands in virtual reality (VR). With bimanual hand gestures based on the metaphor of a physical wire, users can (a) create a curve, (b) modify a curve freely, and (c) modify a curve under constraints.

ABSTRACT

3D content authoring in immersive environments has the advantage of allowing users to see a design result on its actual scale in real time. We present a system to intuitively create and modify 3D curve networks using bimanual gestures in virtual reality (VR). Our system provides a rich vocabulary of interactions in which both hands are used harmoniously following simple and intuitive grammar, and supports comprehensive manipulation of 3D curve networks.

CCS CONCEPTS

• **Human-centered computing** → **Interaction techniques**.

KEYWORDS

Virtual reality; bimanual gesture; Bézier curve network

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1 INTRODUCTION

Virtual reality (VR) offers users the ability to directly see objects at their actual sizes, which is useful for 3D content authoring [5, 6]. In such an immersive environment, freehand mid-air drawing of 3D curves is a commonly used method due to its expressiveness. However, the low precision makes it challenging to draw elaborate curves [1].

Our work aims to design a new method for creating 3D curves in VR that balances expressiveness and precision. Hayatpur et al. [4]. showed that using bimanual interactions to define ad hoc geometric constraints, such as planes, rays, and points, enables quick and precise scene manipulations in VR. Applying this finding to curve manipulation, we propose WireSketch, a system that supports 3D curve network creation through intuitive bimanual gestures.

2 WIRESKETCH

In our system, the user creates 3D curve networks using bare-hand interactions. Following the kinematic chain (KC) model of bimanual interaction [3], the user sets constraints with the non-dominant hand (NDH) and manipulates curves with the dominant hand (DH). As a result, the user can manipulate curve networks more quickly and precisely.

The user-generated curve network in our system consists of cubic Bézier curves that are represented as *wires* with the two end points of the wire as *vertices*. In addition to direct manipulation of wires and vertices, the user can move the inner control points. The following subsections describe our hand gesture grammar and the vocabulary of component interactions.

2.1 Types of Gesture

We design gestures in our system by emulating natural interactions with physical objects. The *pinch* gesture is used to specify the position as if pinching a small ball, whereas the *grab* gesture is used to specify the position and the direction simultaneously as if grabbing a bar.

We enable the user to modify curves with higher precision through fluently defining ad hoc geometric constraints by drawing inspiration from the gestures proposed by Bae et al. [2], who used *half* and *full* gestures for constraint definition and object manipulation, respectively. Similarly, in our system, we propose *loose* and *tight* gestures based on the firmness of the hand poses (Figure 2).

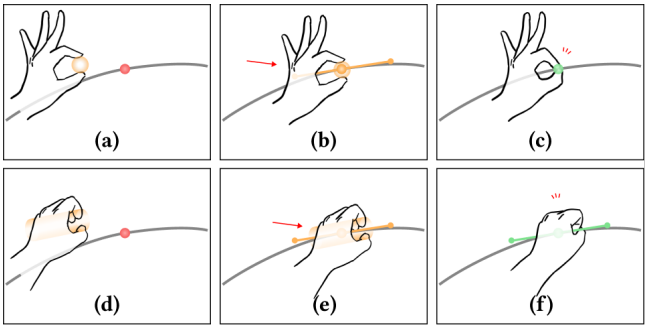

Figure 2: Types of gesture. (a, d) The *loose-pinch* and *loose-grab* gestures create a semi-transparent cursor in the form of a sphere and a cylinder, respectively. (b, e) When the user places the cursor on a vertex, the adjacent control points are displayed. In this state, loose-pinch constrains only the position of the vertex, whereas loose-grab constrains both the position of the vertex and the tangent at the vertex. (c, f) When the user *tight-pinch*es a vertex, the user can modify the position, and when the user *tight-grab*s a vertex, the user can modify both the position and the tangent.

2.2 Create & Delete Wire

The user can create a straight wire in the air with a two-handed tight-pinch gesture (Figure 3), and then bend (Figure 4) or delete (Figure 5) the wire with a two-handed tight-grab gesture.

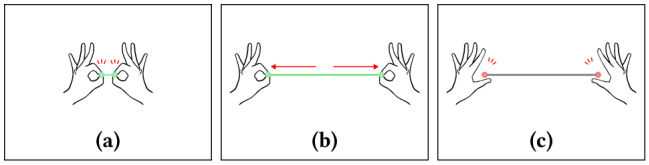

Figure 3: Create. The user (a) tight-pinches with both hands close together in the air to create a straight wire, and then (b) stretches the wire (c) into a desired line.

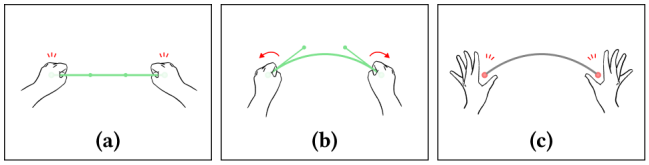

Figure 4: Bend. The user (a) tight-grabs both vertices of a wire and (b) bends the wire (c) to make a desired curve.

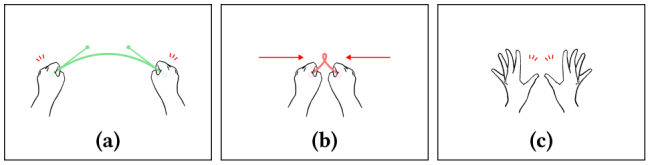

Figure 5: Delete. The user (a) tight-grabs both vertices of a wire, (b) brings them close to each other, and (c) releases them to delete the wire.

2.3 Unimanual Manipulation

The user can move and rotate a part of a wire by tight-pinching or tight-grabbing a vertex with one hand (Figure 6). The user can also create a curve network by moving a vertex (Figure 7) or dividing a wire (Figure 8). In addition, the user can grab and move an entire curve network (Figure 9).

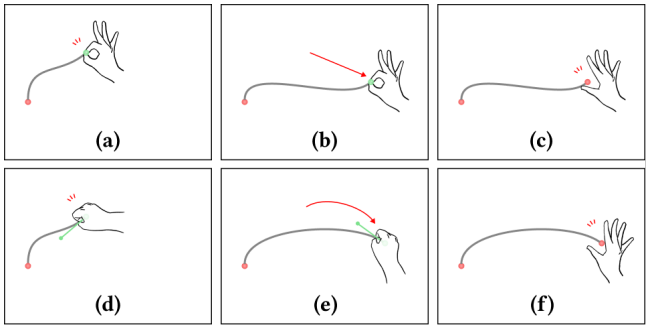

Figure 6: Move vertex. (a-c) The user tight-pinches a vertex and moves it to change the position of the vertex without changing the tangent at the vertex. (d-f) The user tight-grabs a vertex and moves it to change both the position of the vertex and the tangent at the vertex.

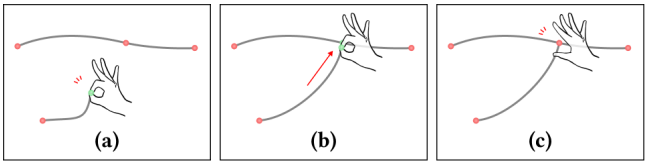

Figure 7: Connect. The user (a) tight-pinches a vertex of a wire and (b) releases it sufficiently close to a vertex of another wire (c) to merge the vertices and form a curve network.

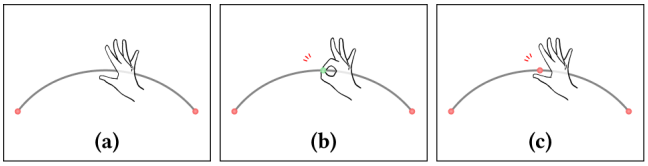

Figure 8: Divide. The user (a-b) tight-pinches in the middle of a wire (c) to create a new vertex dividing the wire into two.

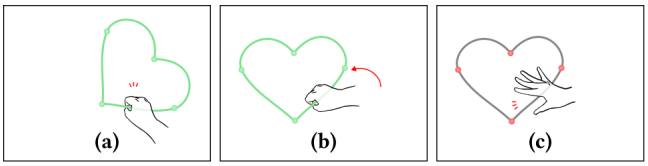

Figure 9: Relocate. (a) The user tight-grabs a wire while avoiding its vertices (b-c) to move and rotate the entire curve network without deformation.

2.4 Bimanual Manipulation

By making a loose gesture with the NDH to set a constraint and then making a tight gesture with the DH to manipulate a curve, the user can separate a wire from a constrained curve network (Figure 10), or precisely modify a curve by moving the control points under a constraint (Figure 11).

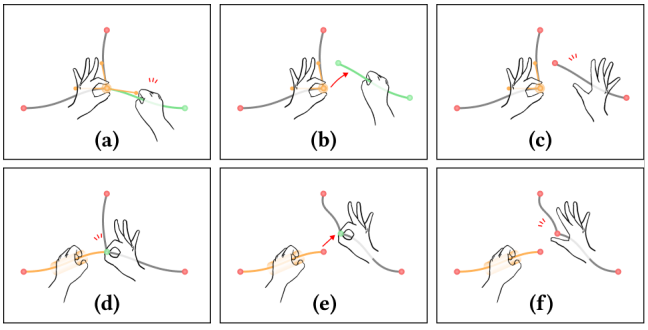

Figure 10: Separate. For multiple wires connected to a single vertex, (a-c) the user loose-pinches the vertex with the NDH and tight-grabs one of the wires with the DH to separate the wire from the vertex. In the same situation, (d-f) the user loose-grabs a wire with the NDH and tight-pinches the vertex with the DH to separate the other wires from the vertex.

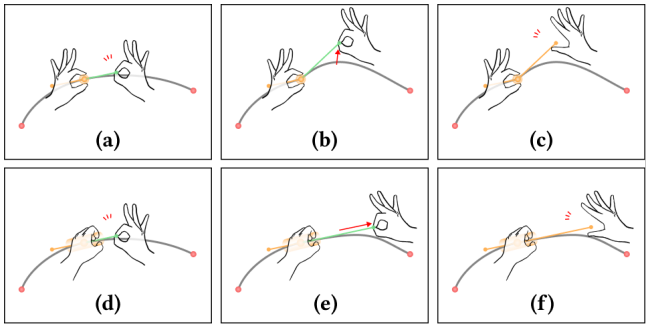

Figure 11: Move control point. (a-c) The user loose-pinches a vertex with the NDH and tight-pinches an adjacent control point with the DH to move it freely. (d-f) The user loose-grabs a vertex with the NDH and tight-pinches an adjacent control point with the DH to move it along the constrained tangent at the vertex.

3 IMPLEMENTATION

We implemented our system using the Unity 3D engine and the Meta Quest 2 VR headset supporting hand recognition. We created a full-scale car model using our system to demonstrate that it can be used to author complex life-size 3D curve networks (Figure 1).

4 CONCLUSION & FUTURE WORK

We propose WireSketch, a system for authoring 3D curve networks. First, we design simple gesture grammar based on people's natural hand pose and pose firmness when interacting with physical wires. Second, we build a rich vocabulary of interactions that supports comprehensive manipulation of 3D curve networks.

For future work, we will evaluate the system's usefulness by measuring its qualitative and quantitative performances in a user study. In addition, we will expand our system to support the creation and manipulation of NURBS surfaces.

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