HapTwist: Creating Interactive Haptic Proxies in Virtual Reality Using Low-cost Twistable Artefacts

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Figure 1: (a) Virtual pistol model, (b) generated Rubik's Twist shape, (c) real object, and (d) the physical haptic proxy, (e - h) Examples of HapTwist-generated interactive VR haptic proxies, left to right: machine gun, steering wheel, ping-pong paddle, and fishing rod.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**;

KEYWORDS

Virtual Reality; Hand Grasp; Haptics; Rubik's Twist; Toolkit.

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1 INTRODUCTION

In recent years, virtual reality (VR) with head-mounted displays is gaining an increasing amount of attention in the consumer market, with highly realistic visual and audio contents. However, it is still challenging to use these VR devices with pre-fabricated shapes of controllers to simulate realistic haptic/kinesthetic information (i.e. the shape, the size, and the weight) of the virtual objects.

Existing VR haptic instruments can be classified as active haptics (AH) and passive haptics (PH). While the AH devices [Benko et al. 2016; Heo et al. 2018; Strasnick et al. 2018; Whitmire et al. 2018] usually provide high responsive speed and controllability, they are often bulky, heavy, time- and money-consuming to set up, and limited in expressiveness for rendering the details of shapes. In addition, most existing AH controllers only supported single-hand/finger interaction with the restriction of hand postures. Alternatively, PH [Simeone et al. 2015] leveraged physical objects as the VR haptic proxies by either manual or digital fabrication (e.g. 3D printing). While physical objects demonstrate benefits in VR by reducing the cost and the complexity of the haptic devices, research also points the drawback of requiring specific physical objects for visually different virtual object [Simeone et al. 2015], leading to low scalability and reusability. More recently, shape-changing interfaces were adopted as a type of passive haptic proxy [McClelland et al. 2017]. However, the need of users' in-VR shape manipulation may require careful design of the VR scenario and storyline. To make haptic feedback effective, low-cost, and reusable in VR, there is a strong need for a construction toolkit for facilitating the creation of haptic devices and leveraging the advantages of both AH and PH.

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2 HAPTWIST

In this demonstration, we present HapTwist, a toolkit that facilitates the creation of interactive haptic proxies for hand-graspable VR objects. The toolkit leverages Rubik's Twists (RTs, also known as Rubik's Snake), a type of low-cost twistable artefacts. Prior to the toolkit development, our pilot studies validated the feasibility and effectiveness of using RTs to create VR haptic proxies. We also observed the need of scaffolding and guidance in the physical shape creation, and the lack of active interactivity in the constructed proxies, motivating the development of the HapTwist toolkit.

As shown in Fig. 2, The HapTwist toolkit consists of the algorithm that generates RT-based structures, and a set of software scaffoldings and hardware modules to support the interactivity

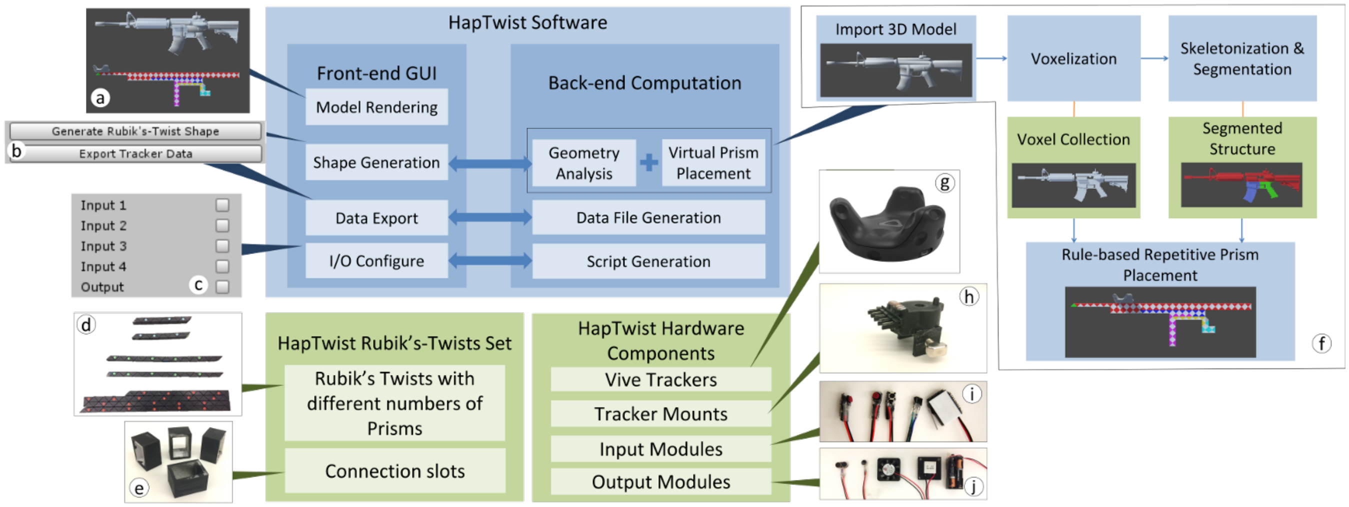

Figure 2: System Diagram of HapTwist: (a) 3D model rendering in Unity, (b) Graphical user interface (GUI) for shape generation and data export, (c) GUI for I/O settings on individual prism, (d) Rubik's Twists, (e) Connection slots for Rubik?s-Twist Assembly, (f) Algorithmic pipeline for shape generation, (g) Vive tracker, (h) tracker mount with POGO pin connections, (i) Input modules: push buttons and trigger, (j) Output modules, left to right: dual vibrators, single vibrator, fan, thermo-electric (TEC) module, power supply for fan and TEC module.

of the haptic proxies. The HapTwist software interface can generate the RT-based shapes by geometrically analysing the 3D models through voxelization and skeletonization (Fig. 2f), and provide guidance for physical construction. We implemented the algorithm as a Unity plug-in (Fig. 2b & c) with the feature of importing 3D models. As the generated shape may involve the assembly of multiple RTs, the plug-in computes the number and the types of RTs needed to be used, and highlights different RTs in different colors. For the generated shapes, the plug-in also labels the prisms with the number IDs, to assist the identification of the twisted positions in the real RTs.

With the generated shape, the plug-in allows the user to indicate the attachments of the Vive tracker and the input/output (I/O) hardware components in the physical proxies. Furthermore, the plug-in can export the relative position and the orientation of the Vive tracker to the 3D model, and generate a C#-based scripting template for the haptic proxy. Users can import these generated data and script in their own Unity VR project.

The HapTwist hardware modules include a set of RTs with different numbers of triangular prisms (Fig. 2d), the Vive trackers (Fig. 2g) with 3D-printed mounting structures (Fig. 2h), and a list of input components (Fig. 2i, e.g. push buttons, switches, and triggers) and output components (Fig. 2j, e.g., flat vibrators, fans, and thermo-electric elements). Furthermore, we fabricated a set of connection slots (Fig. 2e) for the assembly of multiple RTs. Upon finishing the physical shape construction, the user can fix the tracker on the physical RT shape using the mounting structure. The tracker-mounting structures provide male-style pinouts for the POGO pins in the Vive trackers, allowing easy connection of the I/O components. Fig 1e - h show the examples of the haptic proxies created using HapTwist.

3 DEMONSTRATION SCENARIO

We will demonstrate HapTwist toolkit with a set of common VR scenarios, including a ping-pong game, a driving simulation, a shooting game with pistols and machine guns, and a farming simulation with different hand tools (e.g., fishing rod, axe, watering pot, and gardening scissors), as shown in the submitted video. Besides demonstrating the usage of HapTwist, we will also guide the audience to use HapTwist to create the haptic proxies for the hand-graspable objects in the selected VR scenario, and experience the haptic proxies they created in VR.

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