

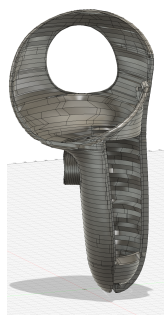
Track-Anything-3D: Integrating the Tracking Electronics of the Meta Quest 3 Touch Controllers into Arbitrary 3D-Fabricated Objects

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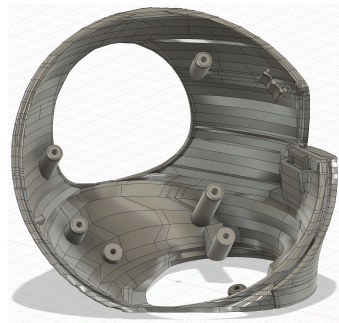
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(a) The full 3D-modelled controller casing without the battery cover.



(b) Top-part of the casing, where only the tracking electronics reside, consisting of holes for the trigger and handle, providing pick-ups for the screws.



(c) A 3D-fabricated medieval fantasy hammer that allows for embedding the controller's tracking electronics into its hammer head.



(d) This recreated controller has a thinner grip compared to the original.

Figure 1: We present an open-source 3D-model of the Meta Quest 3 Touch controller's casing, shown in (a). The upper part, shown in (b), contains holders and screw holes to embed the controller's tracking electronics. Its mesh can be used to merge it with other 3D meshes, so that physical proxy objects can be created that allow for embedding the tracking electronics directly into the object. One example is shown in (c), where a 3D-printed medieval hammer now contains the tracking electronics of the Meta Quest 3 Touch controller and can be directly tracked by the Meta Quest 3. In (d), we also 3D-printed a clone of the original controller with a thinner grip for increased ergonomics as a proof-of-concept.

Abstract

Many current Extended Reality Head-Mounted Displays use hand-held controllers to track the user's hands. However, these controllers have inherent limitations, leading researchers to seek proxy objects instead. Enabling proxies in Virtual Reality is challenging because they must integrate with the HMD's tracking system for user interaction. Researchers often resort to external tracking systems like OptiTrack, which are complex to integrate, or other solutions incompatible with the Meta Quest 3, the most popular standalone HMD. Our work overcomes these limitations by creating an artifact: a 3D model of the Meta Quest 3 Touch controllers that embeds their tracking electronics into arbitrary 3D objects. With our model,

any proxy object is easily tracked by the Meta Quest 3's inside-out tracking system. We release our artifact as open-source.

CCS Concepts

• **Human-centered computing** → *Human computer interaction (HCI); Virtual reality.*

Keywords

Virtual Reality, Controllers, Manufacturing, 3D-Model

1 Introduction

Most interactions with objects in Virtual Reality (VR) make use of hand-held controllers or natural hand-tracking. Hand-held controllers are most often delivered as parts of a Head-Mounted Display (HMD), with prominent examples being the controllers for the Meta Quest or for the HTC Vive. People have these controllers in their hands and interact with objects inside the Virtual Environment (VE) via the spatial tracking of the controllers by the HMD. Button



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presses allow for further control. In turn, natural hand-tracking by the HMD tracks the users' hands directly without them having to hold a dedicated object, such as a controller, in their hands [8].

While controllers enable efficient interaction in VR, they also have limitations. The main concern is that their passive haptics, such as their shape, texture, and weight, are always the same and they do not resemble the expected properties of the associated virtual object. For instance, imagine picking up a heavy hammer in VR – the associated haptic experience, such as feeling the actual handle or experiencing the weight, is not conveyed by controllers, nor by natural hand-tracking. That is why researchers have created proxy objects in VR, so that arbitrary objects' haptics can be conveyed to a VR user.

There are a number of prominent examples of such haptics in VR. For example, Zenner and Krueger have created a proxy object called “Drag:on” that comes in the shape of a hand-held fan, which is able to adjust its surface area, so that the user can feel the changed drag and rotational inertia [18]. They have also created another proxy called “Shifty”, which can change its internal weight distribution, increasing the perception of virtual objects [19]. Another example is “PumpVR” by Kalus et al., who also explored changes in weight by applying liquid mass transfer [12].

While this is an established research field, many researchers face the same common challenge: once they create their proxy object, it cannot be tracked directly by the HMD. Since the object lacks the tracking electronics of the original controllers, the HMD cannot track it, and information from the users' hands is often unreliable. That is why researchers resort to external or additional tracking systems: Drag:on and PumpVR used the HTC Vive Tracker add-on, whereas Shifty used OptiTrack as an external tracking solution. Since today's HMDs cannot track arbitrary objects, this necessitates the use of expensive additional hardware.

We address these issues by providing an artifact. Using 3D scanners and extensive manual layouting, we have created a replica of the casing of the Meta Quest 3 Touch controller, which is one of the most popular standalone HMDs. Figure 1(a) shows the full controller model created in Autodesk's Fusion 360, and Figure 1(b) shows the top part, where only the tracking electronics are embedded. Using our provided open-source replica, the casing can be merged with the mesh of any arbitrary 3D-fabricated object (cf. Figure 1(c)) so that the Meta Quest 3 controller's tracking electronics can be directly embedded. By 3D-printing the result, it becomes possible to create arbitrary 3D-fabricated objects that embed the necessary casing to contain the controller's tracking hardware. Thereby, the necessary hardware can be directly embedded into the proxy object without the need for additional hardware or external tracking systems.

We showcase our artifact through two proof-of-concept: First, we create a replica of the original Meta Quest 3 Touch controller and embed the tracking hardware into the printed 3D-casing. Second, we create an arbitrary example proxy object resembling a medieval fantasy hammer that contains the tracking electronics. We further outline the development process and the process of transferring the tracking electronics, including associated limitations. Through our open-source artifact, we allow for seamless tracking of arbitrary 3D-fabricated objects using the HMD's internal tracking system.

Contribution Statement [16]. Our contribution is an open-source artifact, that is a 3D model of a Meta Quest 3 controller, enabling the creation of arbitrary, trackable proxy objects in Virtual Reality. We showcase this artifact through two proofs-of-concept, one being a replica of the Quest 3 controllers, and the other showcasing an arbitrary 3D-printed object.

2 Related Work

Human-computer interaction researchers have focused on proxy objects that provide passive haptics in Virtual Reality for a considerable time, creating a number of proxy objects for interaction. For example, Zenner and Krueger proposed “Drag:on” in 2019, which is a controller that can unfold like a fan to change weight inertia through air resistance [18]. For tracking by the HMD, they used the HTC Vive Tracker add-on. Earlier, in 2017, they also proposed “Shifty”, a rod-shaped proxy that can shift its weight to enhance object perception in VR; it is externally tracked by the OptiTrack system [19]. In “VRSketch”, Auda et al. explored sketching in VR, where they provided their participants with a hand-held pen that was also tracked externally by OptiTrack [1]. Beyond hand-held proxy objects, Knierim et al. proposed “Tactile Drones”, a VR haptic feedback system in which caged quadcopters physically contact users at specific body locations to render impacts of virtual objects. Therefore, the quadcopters are tracked using OptiTrack as well [13]. In 2024 and 2023, “MobileGravity” and “PumpVR” by Kalus et al. show hand-held prototypes that can change their weight by transferring liquid mass; their tracking is respectively performed by an HTC Vive Tracker [11, 12]. Monteiro et al. explored a similar approach earlier in 2021 by also moving liquid mass; to track their hand-held device, they constructed a mount into which the VR controller could be inserted as a whole [14]. “Thor's Hammer” is a hand-held proxy object for VR that uses propeller propulsion to generate strong thrusts of air providing force feedback; the tracking is being handled by a VICON tracking system [9]. Also, Whitmire et al. proposed the “Haptic Revolver”, which provides haptics to the fingertips to interact with virtual surfaces [15]. Its positional tracking is being enabled by the HTC Vive Tracker. Moreover, Choi et al. also proposed “CLAW”, which is a multifunctional controller for grasping, touching, and triggering in VR that is also capable of providing haptic feedback; it is also being tracked by the HTC Vive Tracker add-on [5]. Similarly, Yoshida et al. presented “PoCoPo”, a hand-held pin-based shape display that renders different shapes of virtual objects through actuated pins on two opposite sides of the device. Its position in VR is tracked using an attached HTC Vive Tracker as well [17]. Thus, custom-built proxy objects remain common in HCI research on VR, particularly for hand-held haptic interactions. To facilitate the construction of such proxies, Zhu et al. proposed “HapTwist”, a toolkit for creating interactive haptic proxies for hand-graspable virtual objects from low-cost, twistable artefacts. Although the resulting proxies can be augmented with input and output components, their use in VR still relies on additional tracking hardware in the form of an attached HTC Vive Tracker [20].

Research Gap. While researchers have already provided a large number of approaches to exploring hand-held proxy objects in VR, we see that many systems struggle with integration into the

HMD's tracking space. As an observable result, most approaches use external solutions such as expensive external tracking systems (e.g., OptiTrack or VICON) or additional hardware (e.g., the HTC Vive Tracker add-on). With the exception of Monteiro et al. [14], who constructed a dedicated mount into their prototype to fit the hand-held controller into, we find that there is an apparent need for alleviating these challenges. Therefore, we decided to create an artifact that can be merged into any 3D object's mesh and allows for the transfer of the controller's tracking electronics so that the object becomes directly spatially trackable.

3 Development of the 3D Model

Creating the artifact was a two-step process. First, we obtained a point cloud of the original controller through an initial 3D scanning phase. Then, we conducted a CAD modeling phase.

3.1 3D Scanning

To capture the exact physical dimensions and exact curvature of the original Meta Quest 3 controller, we first conducted a 3D scan using a Crealiti Raptor 3D scanner [6]. Our scanning setup enabled us to digitize the physical hardware and generate a high-resolution preliminary mesh as a reference. Using a 3D scanner, we ensured the complex geometry of the controller casing was captured with high fidelity.

3.2 CAD Modelling

Following the scanning process, we imported the generated reference mesh into Autodesk Fusion 360. During the CAD modeling phase, we used the scanned geometry as a dimensional guide to manually construct a clean, optimized digital model from scratch. Particular attention was given to accurately recreating the internal mounting points to ensure that the tracking electronics would securely fit into the custom casing. We also precisely modeled the battery cover and the handle interface to maintain the modularity of the design. The finalized CAD model successfully replicates the essential structure of the original hardware while allowing it to be merged with other 3D-fabricated objects. The process was labor-intensive, since the 3D-scanner yielded a point cloud and all adjustments were done manually, resulting in a Fusion file with over 180 checkpoints.

4 Applying Our Artifact to Arbitrary Objects

The underlying object can be arbitrary but must fit the mount for the main tracking board and the power source. The application of our artifact consists of three steps. First, our 3D-model artifact needs to be downloaded¹. We publish our model as a binary file (.stl, .m3f, in millimeters), and in addition, since we created the model in Autodesk Fusion 360, also as a Fusion 360 project file (.f3d, .f3z). Furthermore, we provide a cross-platform STEP file (.step). Then, the model needs to be merged with any other object, e.g., its 3D mesh. The result can be fabricated in the third step. Finally, the tracking electronics need to be inserted.

4.1 Merging our Model into an Arbitrary Mesh

Our model consists of three individual parts. First, we provide a full replica of the controller casing, exactly scaled as the original controller (see Figure 1(a)). Second, depending on the scenario, we also provide a dedicated model of the battery cover (cf. Figure 2(a)). Third, we provide a dedicated model of only the top part of the controller, where the tracking electronics reside in (cf. Figure 1(b)).

In most cases, it is likely desired to use only the third model, which is the top part of the controller with the tracking electronics, as it is the most compact and minimalistic (cf. Figure 1(b)). However, certain limitations need to be understood to utilize this part correctly: first, the gripper button mechanism is not part of this model; the gripper must be removed, or another solution needs to be found. Second, depending on the placement, the other buttons (e.g., A/B, X/Y, thumbstick, Meta/Menu buttons) might not work, as they may be out of the user's reach. Third, the casing does not include a spot for the vibration motor, which would be at the very bottom of the controller. It can be safely removed, and only its functionality is lost, or another placement solution needs to be found. Finally, a new location for the power source must be provided by the underlying object.

To merge two objects, a 3D model of an arbitrary object needs to be created or downloaded. For our proof-of-concept, we downloaded a model of a medieval fantasy hammer from Thingiverse². The model comes as two STL files, one for the hammer head and one for the handle. Now, depending on the actual software used, the steps of merging the meshes differ. In our workflow, we used Fusion 360 and imported both objects, i.e., the hammer head and our artifact. Then, we created a hole in the hammer head, into which we would move the top part of the controller. To create the hole, we first created a cylinder, moved it into the hammer head's mesh, and performed a cut operation. Then we moved the controller's top part into the resulting hole and performed a merge operation. The result is shown in Figure 2(c). Autodesk provides documentation on using the respective tools to merge and cut meshes [2], they also provide extensive documentation on other Mesh-related operations [3]; however, these steps differ for the concrete software used. This resulted in an STL file that we could print on our 3D printer, a Bambu X1 Carbon [4], with PLA filament.

4.2 Moving the Tracking Electronics

After printing the result, we installed the tracking electronics. First, we removed the battery casing and used a pry tool to remove the black circular case cover from the controller. Next, using a TX5 screwdriver, we removed all screws from the board. This board contains the main tracking circuit, with seven infrared LEDs (IR LED) and an inertial measurement unit, one additional IR LED is located at the very bottom of the controller handle. Then, we removed the ribbon cables from the main board and removed all components. The assembly in our provided model then follows the reversed steps, with first attaching the controller main board with the IR LEDs and then attaching a power source. Appendix 3 provides detailed illustrated instructions on moving the electronics, and so does an article by iFixit [10]. The power supply is primarily

¹Track-Anything-3D on Github: <https://github.com/Florad97/Track-Anything-3D>.

²Thingiverse: Thor's Hammer by skimbal. <https://www.thingiverse.com/thing:17637>. Licensed under CC BY-NC-SA, last accessed August 3, 2026.

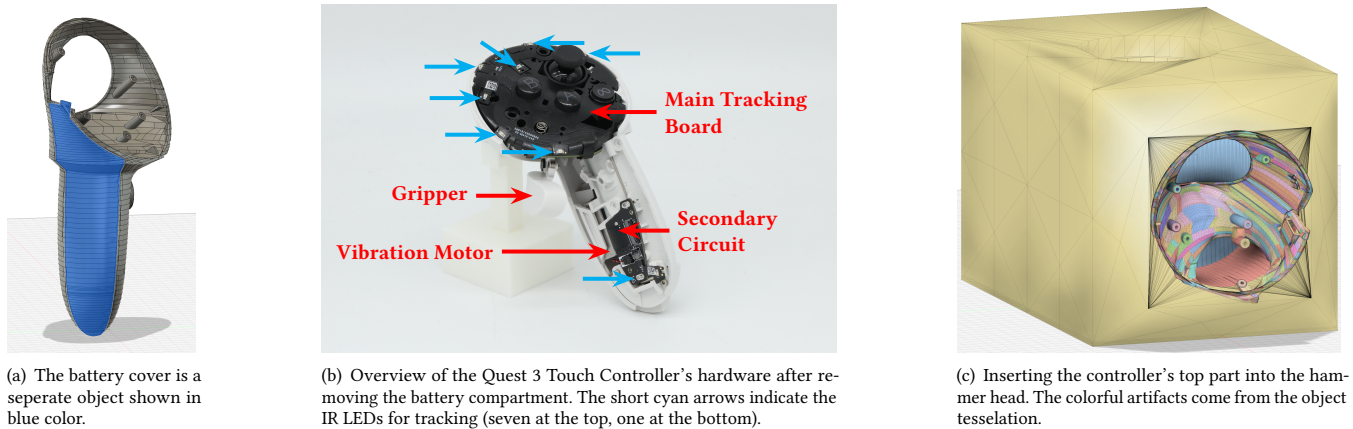


Figure 2: In (a), the provided battery cover is highlighted in blue. In (b), the internals of the original Touch controller are shown and annotated. The main tracking board contains seven IR LEDs for tracking. The secondary circuit connects to the battery and contains one more IR LED. The grey vibration motor is hidden behind the secondary circuit. In (c), a screenshot from Fusion 360 is shown where our artifact is emplaced into the hammer head. The fabricated result is depicted in Figure 1(c).

constrained by the available space inside or on the controller. It can be a regular AA battery that is attached using the original cables in a new location, or even a single button cell (e.g., LR44 1.5V 105mAh). Preliminary testing showed that one LR44, which is one of the tiniest button cells, can power the controllers for up to 0.5 hours; using power sources with greater capacity is, of course, also possible.

5 Limitations

Naturally, our proposed artifact comes with limitations depending on how it is used. First, if only the dedicated model of the controller's top part is used, certain components of the electronics may not be placed efficiently. In particular, the gripper button's functionality might be lost, and the other buttons might be out of reach depending on the placement. Next, the top piece of the controller contains seven IR LEDs [7], which should be placed in the 3D object so that the HMD's cameras can see them. The bottom piece (cf. secondary circuit in Figure 2(b)) also contains one tracking IR LED, which might not be visible by the HMD, depending on its placement. However, a simple, preliminary testing by the authors did not reveal any noticeable impact on the tracking performance. Another feature that might be lost is the vibration motor, which also sits at the very bottom of the controller. Removing these components is feasible, as the main tracking board works without the vibration motor or the gripper button attached. Regarding the underlying 3D object, it is important that its size fits our artifact and that additional space is reserved for the power source. Finally, it must be stated that application developers need to take care of the new pivot point and tracking offset that depends on the underlying 3D model where the tracking electronics are embedded, since the software, by default, would expect that the electronics remain handheld and close to the user's hands. Moreover, while the underlying object can be arbitrary, it must provide sufficient space for the main tracking board and the selected power source.

6 Discussion & Conclusion

Given our proposed artifact, we provide the means to have the tracking electronics of a Meta Quest 3 Touch controller moved into arbitrary 3D-printed objects. Our approach works through merging the meshes of the arbitrary 3D-object with the mesh of our proposed artifact and then moving the original tracking components. This allows for creating proxy objects that do not require any extra tracking hardware, such as external tracking systems or tracking addons, resulting in a low-cost solution. We provide our model in three components: (1) the full, exact-size controller casing, (2) the battery cover, and (3) only the round top part of the controller, where the tracking electronics reside.

We showcase our artifact through two proofs of concept. First, we created a medieval fantasy hammer that acts as an example for any 3D-printed object. The tracking electronics can be integrated, and the tracking system subsequently works; however, one important limitation is that the software needs to know the newly introduced offset and pivot point. Ideally, the IR LEDs should also stay in the view of the HMD, which depends on the actual object used. Yet, preliminary testing did not reveal any meaningful reduction in tracking precision. The hammer can be sufficiently tracked, especially since its inertial measurement unit provides continuous information, even when the tracking electronics go out of sight (e.g., during a hammer swing).

We furthermore created a replica of the hand-held controllers as another proof of concept. This can be useful to adapt the ergonomics of the controller or to recreate the original casing, in case it breaks (e.g., through an accidental impact of the controllers with a wall or floor). For this, we created a slightly smaller and thinner version of the controller, as we believe that this could increase the ergonomics for certain people. We seek to further evaluate these limits in future work, both in terms of how people perceive controllers with different dimensions and properties and how the tracking actually performs. Initial impressions from preliminary testing, however, gave positive indications.

Finally, our artifact also allows us to overcome the limits of the original controllers. For example, lots of flexibility can be gained using new power supplies, which can be lighter and smaller (e.g., using a button cell instead of an AA battery). At the same time, designers are now freely capable of creating various new controller shapes, dimensions, and properties. Thereby, our artifact enables the seamless integration of the tracking electronics into a wide range of new proxy objects for VR, removing the dependency onto external tracking systems or -hardware.

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A Tracking Electronics Assembly



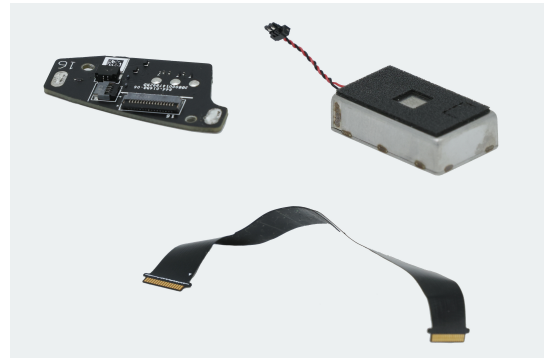
(a) First, the screws need to be removed that are located in the battery compartment below the sticker, to remove one half of the casing.



(b) Then all components can be carefully removed until only the casing remains.



(c) The main tracking board contains the buttons and IR LEDs for tracking. It should be placed in the fabricated object so that the cameras of the Quest HMD can see the LEDs.



(d) Collage of the remaining hardware besides the main tracking board, with the secondary circuit that connects to the battery (top left), the vibration motor (top right), and ribbon cable (bottom).



(e) Next, we first insert the battery into the cut-out hole. It is possible to use 1.5V button cells or regular batteries depending on the space in the object. It is attached to the secondary circuit board.



(f) Finally, we embed the main tracking electronics after attaching the ribbon cable. At last, the black cap needs to be added. The final result is shown in Figure 1(c).

Figure 3: Overview of the necessary steps to move the electronics from the Meta Quest 3 touch controller into our 3D-fabricated hammer. iFixit also provides a video of the disassembly [10]. The assembly follows the reverse steps.