Project Proposal V1 Revision

Team Members and Skills

Our team is made up of Mengxu Xie, Zihao Lin, and Daijie Bao.

Member 1 Mengxu Xie: 3D printing, Laser cutting, Computer aid design.

Member 2 Zihao Lin: Machine design, Circuit analysis.

Member 3 Daijie Bao: Algorithm design and programming, Computer aid design.

Topic and Motivation

The rapid growth of virtual reality interfaces and mobile interactions has catalyzed the development of haptics devices, with most of them grounded and few ungrounded. We want to explore the possibility of ungrounded haptic devices on virtual entertainment, fitness, rehabilitation and strength training. With the motivation to be involved in the research area of ungrounded kinematic devices, our team plans to design a virtual hammer based on the well-established Hapkit. The virtual hammer can serve as a low-cost pedagogical and rehabilitative tool in muscle strength therapy.

Previous Work

Paper Selection 1

A. J. Miller, N. D. Riaziat and J. D. Brown, "An Open-Source Ungrounded Hapkit for Educational Applications," 2021 IEEE World Haptics Conference (WHC), 2021, pp. 1155-1155, doi: 10.1109/WHC49131.2021.9517254.

https://ieeexplore.ieee.org/document/9517254

This paper proposed an unground haptic device. To achieve ungrounded kinesthetic feedback, the device uses existing Hapkit hardware modified with 3D printing. Using Arduino and Processing code, the author created a demo that simulates ungrounded impacts like hitting a tennis ball. We could use their ungrounded Hapkit-based device design as a system design reference for our project.

Paper Selection 2

Walker, J.M., Culbertson, H., Raitor, M., & Okamura, A.M. (2018). Haptic Orientation Guidance Using Two Parallel Double-Gimbal Control Moment Gyroscopes. *IEEE Transactions on Haptics, 11*, 267-278.

https://www.semanticscholar.org/paper/Haptic-Orientation-Guidance-Using-Two-Parallel-Walker-Culbertson/4b78665e4687cf361a72c2555cbaaa3722bfef29

A system of two double-gimbal control moment gyroscopes is proposed to tender kinesthetic haptic feedback for ungrounded haptic devices in this paper. Furthermore, it can provide feedback for guidance and interactions in the virtual environment. In our project, it can guide the Hapkit hammer motion.

Paper Selection 3

Z. A. Zook, O. O. Ozor-Ilo, G. T. Zook and M. K. O'Malley, "Snaptics: Low-Cost Open-Source Hardware for Wearable Multi-Sensory Haptics," 2021 IEEE World Haptics Conference (WHC), 2021, pp. 925-930, doi: 10.1109/WHC49131.2021.9517172.

https://ieeexplore.ieee.org/abstract/document/9517172

A low-cost haptics platform called "Snaptics" was created for the rapid prototyping of wearable haptic devices in this paper. For our project, it gave us inspiration on how to provide an accessible and adaptable solution in device design.

Paper Selection 4

B. Sauvet, T. Laliberté, C. Gosselin, "Design, analysis and experimental validation of an ungrounded haptic interface using a piezoelectric actuator", Mechatronics, Volume 45, 2017, Pages 100-109, ISSN 0957-4158, https://doi.org/10.1016/j.mechatronics.2017.06.006.

https://doi.org/10.1016/j.mechatronics.2017.06.006

The paper illustrates a novel ungrounded haptic device food spatial guidance. Dynamic analysis of the device is conducted and the dynamic characterization for optimizing the human perception is highlighted. From this paper we learn to adjust force feedback according to device dynamic.

Paper Selection 5

Swindells, Colin & Unden, Alex & Sang, Tao. (2003). TorqueBAR: An ungrounded haptic feedback device. 52-59. 10.1145/958432.958445.

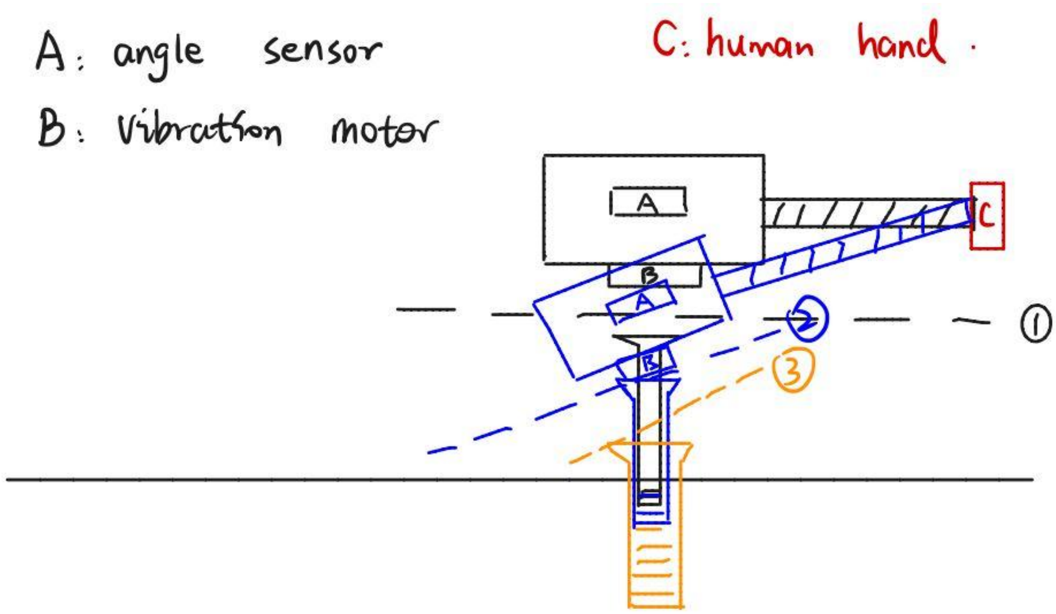
https://dl.acm.org/doi/10.1145/958432.958445

In this paper, a prototype for a new haptic feedback device is presented, the TorqueBAR. Using a kinesthetic awareness of dynamic inertia, this device simulates complex coupled motion both as an input and display. We could use the motion simulation design of their device as a motion control reference design for our project.

Project Plan

Our idea is to design a Hapkit-based virtual game hammer which can simulate the tactile sensation of hitting a nail. Inspired by the Hapkit tennis racket, our starting point is a hammer shape device with a Hapkit installed. In order to increase the feasibility of the project and to reduce the budget, we decided to make efficient use of the existing Hapkit equipment for retrofitting. Vibration motors are attached to the head of the hammer to render hitting. IMUs are used and secured to the handle of the hammer, which measures the Euler angles relative to the gravity vector. According to the returned angle measured by IMU during the interaction with a virtual nail, the Hapkit device can then generate corresponding forces. The IMU will record the base position. Referring to the base position, the moment of inertia of the manipulator is controlled, and the impedance of free space can be rendered.

We design another IMU placed on the ground as a virtual nail. When the hammer is held straight up on the base position, the relative angle difference of two IMUs is set to 90 degree. To successfully hit the nail, the relative angle difference should be reduced to 45 degree with a considerable velocity and acceleration by design for example. When the hammer successfully hits the nail with the relative angle difference reduced to 45 degree, a vibration will be generated. The second time when the hammer returns to its base position, the relative angle difference to hit the nail becomes 30 degrees which simulates the nail moving down. If the relative angle difference during striking does not reach 30 degrees, or the striking velocity and acceleration are too small, the hit will be deemed as unsuccessful. The relative angle difference will keep increasing every time the nail is successfully hit, until it reaches 0 degrees which means the nail is completely struck into a wooden board.



A custom hammer handle will be printed for the virtual hammer environment. Also, a Hapkit board plate will be printed and attached to the base of the Hapkit to ensure that the motor shaft magnet and the MR sensor are aligned. To make the center of gravity of the Hapkit similar to that of a real hammer, we placed the IMU on the handle of the hammer and close to the base side. To simulate the vibration of a hammer hitting a nail, a vibration motor will be added to the side of the Hapkit sector.

Checkpoint 1: Wednesday, November 2

Finalize our hammer design; Order for IMU and vibration motor is placed

Checkpoint 2: Wednesday, November 9

Handle of hammer is 3D printed and laser cut; Control Algorithm for IMU is developed

Checkpoint 3: Wednesday, November 16

Hammer is fully assembled; Control Algorithm for IMU is developed

Checkpoint 4: Wednesday, November 30

Finish Control Algorithm for IMU and start testing the entire system

Checkpoint 5: Wednesday, December 7

Debugging and Solving existing problems; Prepare for demo

Final project demos: Tuesday, December 13 (Design Day)
User study protocol due: Monday, December 19
Final report: Monday, December 19