Mixed Reality: Oppositional Blended Force Feedback Design Studies  
  
  
**Abstract:**  
As more of our daily experiences become mediated by virtual objects, and in virtual environments, the boundary between the virtual and the physical will become increasingly blurred and blended. This shift necessitates the development of novel user interfaces, and related liminal tools, that can give users the ability to easily and fluently move into a Mixed Reality scenarios. Mixed Reality can be defined as “a particular subset of Virtual Reality (VR) related technologies that involve the merging of real and virtual worlds somewhere along the "virtuality continuum" which connects completely real environments to completely virtual ones.” [1]  
  
 In this paper we develop and discuss two approaches to the design of Mixed Reality. In the first scenario, we have tasked users to manipulate both a virtual and physical nut using the same tool (a pair of pliers). In the second scenario, users are asked to craft an object by pinching both virtual and physical clay between the thumb and the index finger. The former employs a mechanical design, while the latter uses electromagnetic induction. Both can be applied to physical and virtual applications; both augment the tactile sensory experience of the user, while also implementing force feedback to simulate virtual objects. We conclude with a discussion of the merits and limitations of each approach to the design of Mixed Reality applications.  
  
  
**Introduction**

This project explores the development of design modalities that can provide users the sensation of holding objects that exist only virtually, while concurrently providing affordances for interactions with physical objects. These applications allow users the ability to move fluently between physical and virtual objects. Our research explores the following questions:  
  
How might we create force feedback: the physical sensation that there is an object present, even when that object is virtual?   
  
How might we measure space and physical objects in order to reproduce virtual objects and space in virtual environments?  
  
How might we develop tools that can interact fluently between virtual and physical objects?

**Prior Work/Notes**

Our initial prototypes explore two methods, mechanical and electromagnetic: 

The first employs the variable resistance of repelling electromagnetic forces. By controlling the strength of the force, we can reproduce the sensation of a range of densities of materials. Our initial prototype validates the concept:   
  
 <https://vimeo.com/354464898>The second method uses mechanical feedback of servo motors, integrated into simple tools. The motors built into the servo allow us to actuate the force feedback, while the servo’s potentiometer allows us to measure the distance and the force. Imagine a pair of pliers that allows the user to manipulate both physical bolts with virtual nuts. This technique could be applied to a range of tools such as pliers, scissors, tweezers, and tongs. Our initial prototype for this method is also promising:  
   
<https://vimeo.com/496527660>

A picture containing indoor, floor, spectacles

Description automatically generated  
Figure 1:  Blended augmented reality pliers using mechanical force feedback.  
  
  
In addition to aforementioned applications, these methods for oppositional blended force feedback might be applied to scenarios where touch is especially important. The relationship between the mind, eye, and the hand are of special concern to the craftsperson. The potter’s wheel is one such application where we could develop synchronous environments, allowing for the concurrent crafting of both physical and virtual objects.   
  
Imagine being able to feel the pot between your palms as it spins. Squeeze inwards to make the pot thinner at that location, and move outwards to make the pot wider. Also, is it possible to create an additional smaller set of magnets (or possibly just non-magnetic inductive coils) on the index finger and thumb? That way the person can feel smaller / more precise interactions like the lip of the pot.

Why do we wear inductive chargers on the fingers?

When making pottery, hand and finger precision in delicate areas is very important. However, there is a common problem when porting this and other precise activities to virtual reality - visual finger tracking methods can be easily confused. If an individual finger is not visible to the cameras, it cannot be represented in VR. This commonly occurs if the back of the hand or other fingers get in the way, although the position of the hand is still known in this case. To solve this problem, we introduce small finger mounted inductive chargers. These can be used in pairs to measure small distances very precisely and the lightweight of the coils prevents bulkiness and muscle fatigue.

Continuing the example of a virtual pottery creation tool, the primary interaction would involve pinching the clay between the thumb and the index finger. The primary transmitting coil would be attached to the thumb and the second receiving coil would be attached to the index finger. The transmitting coil is powered by the same Arduino which measures the analog values of the receiving coil. When the coils are close together, it works as a complete transformer by electromagnetic induction -energy flows from the coil in the thumb to the coil in the index finger. These inductive chargers are loosely coupled and have the ability to transmit a charge a few centimeters with the amount of charge transmitted depending on the distance between the two coils. This can be translated into a pinch gesture as this value also shows the distance between the index finger and the thumb. This is perfect for detecting precise pinch distances when making the lip of a pot and when making small patterns.

How do we get haptic feedback?

For haptic feedback, maybe we can put a vibro tactile motor on the fingernail. Alternatively, we could reuse the original magnet idea but make it a lot smaller. We would put the magnets on the fingernails instead of the finger pad in order to prevent the electromagnetic forces interfering with each other. However, my biggest problem with the magnet idea is that it might burn the fingers.

Another method that came to my mind for haptic feedback on the palm involves using springs. A very rough drawing is shown below.

Diagram

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Springs are attached to a 2”x2” 3D printed part. As you can see the image, the user has to put their hand through the gap where the springs and the servo motor are. When the person brings their hand closer to a solid surface, the shaft of the servo motor rotates clockwise decreasing the size of the gap and increasing the pressure on the palm. When the hands are further apart, the shaft rotates anticlockwise reducing the pressure on the palm.

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**Precedent Work/Works Cited**  
  
[1] [Milgram et al., 1994](https://www.sciencedirect.com/science/article/pii/S1474667017417241?via%3Dihub#bbib0060) Milgram P.**A Taxonomy of Mixed Reality Visual Displays** IEICE Transactions on Information Systems, E77-D (12) (1994)

<https://www.researchgate.net/publication/231514051_A_Taxonomy_of_Mixed_Reality_Visual_Displays>  
  
[2] Seungwoo Je, Minkyeong Lee, Yoonji Kim, Liwei Chan, Xing-Dong Yang, and Andrea Bianchi. 2018. PokeRing: Notifications by Poking Around the Finger. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18). Association for Computing Machinery, New York, NY, USA, Paper 542, 1–10. DOI:  
  
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[3] Nianlong Li, Han-Jong Kim, LuYao Shen, Feng Tian, Teng Han, Xing-Dong Yang, and Tek-Jin Nam. 2020. HapLinkage: Prototyping Haptic Proxies for Virtual Hand Tools Using Linkage Mechanism. In Proceedings of the 33rd Annual ACM Symposium on User Interface Software and Technology (UIST '20). Association for Computing Machinery, New York, NY, USA, 1261–1274. DOI:https://doi.org/10.1145/3379337.3415812

<https://dl.acm.org/doi/10.1145/3379337.3415812>  
  
  
**Conference Info**

Conference deadlines

UIST - April 1st Deadline  
https://uist.acm.org/uist2020/  
  
The ACM Symposium on User Interface Software and Technology (UIST) is the premier forum for innovations in human-computer interfaces. Sponsored by ACM special interest groups on computer-human interaction (SIGCHI) and computer graphics (SIGGRAPH), UIST brings together people from diverse areas including graphical & web user interfaces, tangible & ubiquitous computing, virtual & augmented reality, multimedia, new input & output devices, and CSCW. The intimate size and intensive program make UIST an ideal opportunity to exchange research results and ideas.

Other conferences (later submission date)

TEI - July (Abstract Submission)

CHI - September

**Google Doc**  
  
https://docs.google.com/document/d/1hUGFoeax5aKTzY5zVAPCcb5PsswySHLt8j1vjtReXU8/edit?usp=sharing