Master of Design · Interaction Design · Project 2

Interactions for Sketching in VR

Exploring interactions for sketching with one hand in Virtual Reality

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Declaration

I hereby declare that the project entitled “Interactions for Sketching in VR : Exploring interactions for sketching with one hand in Virtual Reality” submitted to IDC School of Design, Indian Institute of Technology, Bombay, is a record of an original work done by me, Karan Tanna, under the guidance of Prof. Jayesh Pillai. I also declare that the written document represents my ideas in my own words and where others ideas or words have been included, I have adequately cited and referenced the original sources.

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Approval Sheet

The project titled "Interactions for Sketching in VR : Exploring interactions for sketching with one hand in Virtual Reality" by Karan Tanna, is approved for partial fulfillment of the requirement for the degree of Master of Design' in Interaction Design.

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My heartfelt appreciation extends to all my classmates, study participants, and the institutes that supported me throughout this project. Finally, I want to express my deepest gratitude to my parents for their unwavering belief and unfaltering support, even during the most challenging times.

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Abstract

This project investigates how VR technology can address accessibility challenges for individuals with locomotor disabilities, particularly those with single-handed mobility issues. It underscores the global need to cater to this demographic and explores transformative potential in enhancing accessibility of VR. The project involves designing and prototyping novel VR interactions for one-handed users on devices like Meta Quest 2 or Quest Pro, aiming to create inclusive experiences and advance digital equity. We tested existing interactions for sketching in VR like Gravity Sketch and evaluated them. Based on that, we conceptualized and designed hand-tracking interactions for one-handed sketching, moving away from dual-controller setups, with a focus on intuitive techniques for VR sketching. These include interactions for drawing, selecting tools, editing tools, and selecting colors. Later, these interactions were tested and validated but indicated the need for further enhancement as well.

Introduction

According to the World Health Organization and World Bank, about 15% of the global population, or over one billion people, live with some form of disability [1]. Among them, locomotor disabilities (LD) significantly impact individuals' ability to move and control their bodies, posing challenges in both physical and digital environments. In the digital era, while technology offers transformative potential to bridge gaps and remove barriers, many still struggle with accessing and using these technologies due to inadequate inclusive design. VR technology, utilizing gesture recognition, voice commands, haptic feedback, and adaptive interfaces, holds promise for enhancing accessibility for people with locomotor disabilities by improving navigation, information access, and social participation. Prof. Hugh Herr of MIT Media Lab emphasizes, "Great design leads to just absolute joy and human expression," highlighting the critical need for technology that works for everyone [2]. Personally, I resonate with this perspective, having experienced how improved access can positively transform lives and inspire change.

Motivation

Facing the challenge of using only one hand due to a disability has made daily tasks—from tying shoelaces and cutting nails to playing games and driving—significantly difficult. While I found alternative methods to cope, I realized not everyone has access to such resources. My first experience with the Oculus headset was discouraging due to difficulties with controllers, impacting my interaction with applications like Gravity Sketch and games, particularly for users with disabilities. This project aims to develop inclusive, adaptable interactions that minimize reliance on controllers, offering individuals with one-handed locomotor disabilities new opportunities to explore and engage with various applications.

Fig. 1(a) : Driving a car as PwD with LD

Fig. 1(b) : First experience with Oculus

1. Project Details

1.1 Goal

This project aims to prototype and assess VR sketching techniques specifically for individuals with locomotor disabilities, including those with amputated limbs, without relying on traditional controllers. The focus is on fundamental interactions like drawing, color manipulation, tool access, and erasing within the VR environment. These tailored methods seek to enhance the creative experience for users with locomotor disabilities and could also benefit users without mobility challenges. The project emphasizes improving accessibility in VR.

1.2 Opportunity Space

Meta Quest Pro is a phenomenal headset device to engage with VR enviornment. It has ability to detect hands and map bodily features and generate the same in virtual enviornment. The controller that exists currently are limiting and forced technological limitations do not allow users to engage with bodily gestures in VR world. For example, if I have to move my chair in real world I can move it with my hands, or move it with my legs or push it with my arms if my hands are amputed. However, one can not engage with VR world in Quest if one can not hold the controller or do not have fingers to make pre-designated system gestures.

1.3 Scope and Limitations

While this project aims to provide valuable insights into the intersection of VR and locomotor disabilities, it is important to acknowledge certain limitations and the scope of the project.

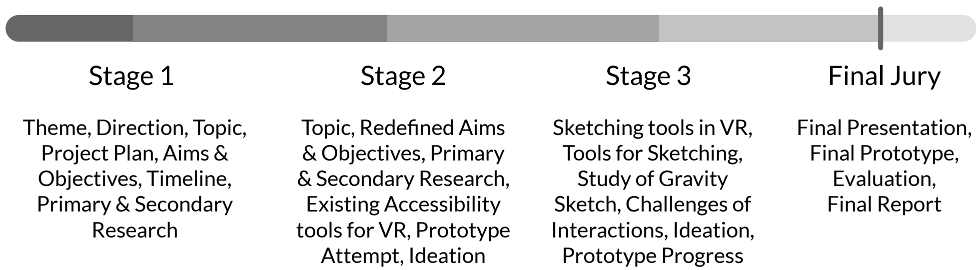
Scope :

- Examination of the current interactions for sketching in VR.
- Exploration of user needs and challenges faced by individuals with locomotor disabilities when interacting with sketching apps in VR.
- Assessment of innovative design strategies and interaction paradigms tailored to meet the specific requirements of this user group.
- Investigation into existing VR hardware and software solutions that cater to locomotor disabilities.
- Ideation and design of new interaction concepts and interfaces specifically aimed at enhancing accessibility for individuals with locomotor disabilities for Sketching in VR.
- Development of prototypes for the designed VR interactions to assess their feasibility and effectiveness for both disabled and abled users.

Limitations :

- Locomotor disabilities encompass a wide range of conditions, each with its unique challenges and requirements. Hence, this project will only address people with one functioning hand and having regular head movement.
- The project will identify various pain points for one handed users while sketching in VR, however, the prototype created for the designed VR interactions would only consist of drawing, colour selection, tool access and erasing only due to time restrictions and limited skillset.
- Empirical data on the experiences and preferences of users with locomotor disabilities in VR environments is limited. Therefore, some aspects of this project may rely on theoretical frameworks and expert opinions.

1.4 Timeline



2. Secondary Research

This literature review provides an overview of research and developments at the intersection of VR technologies and accessibility for individuals with locomotor disabilities, focusing on the current state of accessibility and VR's impact on their lives.

2.1 Evolution of VR

The evolution of Virtual Reality (VR) devices has been shaped by significant breakthroughs, starting in 1838 when Sir Charles Wheatstone introduced "stereopsis," the brain's ability to merge two images into 3D perception. This concept led to the creation of stereoscopes, which simulated depth with image pairs. Today, stereoscopic displays remain crucial in AR/VR systems, enhancing immersion by adding depth to digital images.

VR technology saw little advancement until Morton Heilig's 1956 Sensorama [Fig.2(A)], a multi-sensory booth providing 3D experiences with audio, vibrations, scents, and spatial effects. The Telesphere Mask, an early head-mounted display (HMD), was patented, marking a significant progress in VR development.

Fig. 2(a) : Sensorama, 1956

Fig. 2(b) : Sword of Damocles

In the 1960s, Ivan Sutherland introduced "The Sword of Damocles," the first VR HMD tethered to a computer. In 1985, VPL Research, founded by Jaron Lanier and Thomas Zimmerman, advanced VR with goggles, gloves, and DataGloves. By 1989, NASA's Virtual Environment Workstation Project added real-time binaural 3D audio.

Despite early attempts like Sega's VR-1 and Nintendo's Virtual Boy facing limitations, VR evolved dramatically with Palmer Luckey's Oculus Rift, which revolutionized the field with its wide field of vision and led to Meta's acquisition and further advancements.

Fig. 2(c) : Oculus Rift

Today, tech giants like Microsoft, Google, HTC, and Apple are advancing immersive technology with devices such as Google Glass, HTC Vive, Microsoft HoloLens, and Apple's Vision Pro [Fig. 2(d-h)]. The evolution from stereoscopes to these cutting-edge XR devices highlights the ongoing pursuit of increasingly immersive and interactive experiences.

Fig. 2(d - h) : Hololens, Google Glass, Vision Pro, HTC Hive, Meta Quest Pro

2.2 Examining Current VR Interactions

VR holds significant potential for enhancing learning and social growth among individuals with locomotor disabilities and amputated limbs by providing immersive and inclusive experiences that address physical limitations. It can foster social interaction and reduce isolation, as demonstrated by the study "Virtual Reality Training of Social Skills in Adults with Autism Spectrum Disorder" [Kourtesis et al. 2023, 336, p. 13], which shows how VR can create safe spaces for social engagement. However, reliance on handheld controllers poses challenges for users with limited dexterity, as noted in "Evaluating Accessibility Features Designed for Virtual Reality Context" [Teófilo et al. 2018, p. 1-6], which highlights the difficulties faced by individuals with mobility impairments in using these controllers effectively.

2.3 Limitations of Current Interactions

- Navigation and control mechanisms of OS interfaces often rely on precise mouse and keyboard inputs, posing challenges for individuals with locomotor disabilities.
- Those with motor impairments may struggle with fine motor control, making effective use of a mouse or keyboard difficult.
- Studies like "Evaluation of Alternative Computer Input Devices Used by People with Disabilities" highlight the need for alternative input methods.
- Voice recognition and dictation systems improve accessibility but may lack the accuracy needed for efficient OS control and may not be suitable for users with vocal limitations.
- Customization and adaptability of OS interfaces are often insufficient, limiting options for users to tailor the interface to their needs.
- Individuals with limited mobility may benefit from customizable shortcuts or gesture-based controls, which are not always available or user-friendly.
- Availability and compatibility of assistive technologies with OS platforms can be problematic, as some devices and software may not integrate seamlessly or require additional configuration.

2.4 VR Projects For Accessibility

In this section, we will have an overview of related projects and research that have paved the way for my project. Understanding the landscape of prior work is crucial for contextualising the significance of our research and identifying gaps that this project aims to address.

Seeing VR

The "SeeingVR", a collaborative effort between researchers at Microsoft Research, Cornell University, and the University of California, Berkeley, is dedicated to making virtual reality (VR) more accessible and immersive for individuals with vision impairments. VR, while offering unique and immersive experiences, often poses challenges for those with limited or no vision due to its predominantly visual nature. *[Zhao et al., 2019, CHI 111, p. 1-14]*

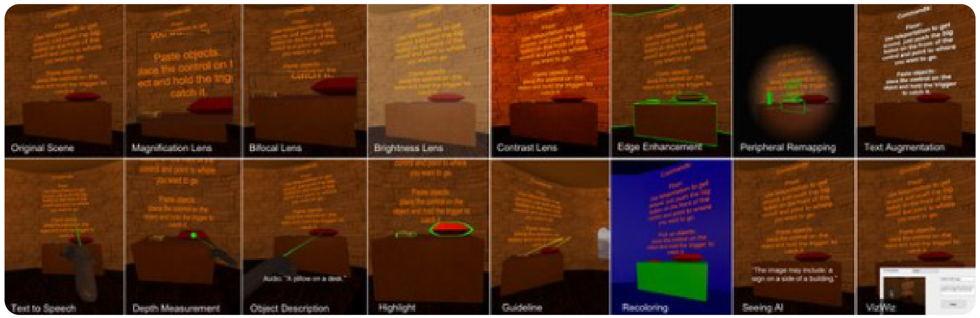


Fig. 3 : All the tools included in Seeing VR

SeeingVR, is a set of 14 tools that enhance a VR application for people with low vision by providing visual and audio augmentations. A user can select, adjust, and combine different tools based on their preferences. Nine of tools modify an existing VR application post hoc via a plugin without developer effort. The rest require simple inputs from developers using a Unity toolkit they created that allows integrating all 14 of low vision support tools during development.

It was evaluated with 11 participants with low vision and showed that SeeingVR enabled users to better enjoy VR and complete tasks more quickly and accurately.

Fig. 4 (a-e) : Screenshots from Seeing VR

Dots : An Inclusive NUI for Spatial Computing

Dots is an innovative two-point body-gesture-recognition system developed by RCA Researchers and showcased at CHI 2020. It uses IMU sensors attached to movable body parts, enabling users to control MR and IoT interfaces through four fundamental 3D interactions: selecting, moving, rotating, and scaling. In their initial study, ten able-bodied participants used restricted body parts to perform these tasks, revealing insights into body movement and interaction.

The follow-up study added constraints, requiring participants to use specific body parts like the right arm, head, or mouth. This helped establish a preliminary calibration system for future prototypes. Researchers then tested the system with two target users—a quadruple amputee and a paralyzed patient with limited upper limb function—to observe practical limitations and possibilities. They found that most interactions and manipulations in 3D space were achievable with just two points of contact.

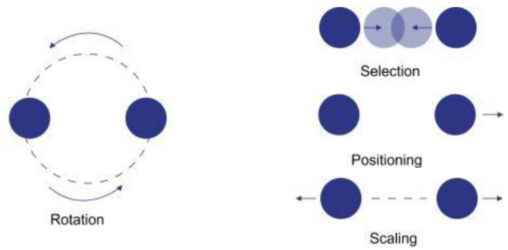


Fig. 4 (f) : Two point system used in the Dots

They defined a two point interaction model as given [Fig. 4(f)]. Selection was done by two points quickly approaching each other. Positioning was changed by one point and the other moves. Scaling is achieved when two points move relative to each other. Two points were rotated around the pivot point and were used to rotate the objects.

To use Dots, users attach two dots to their body parts or objects like tables, enabling interaction through relative movements. Each dot contains an IMU sensor, a Bluetooth module, and a lithium battery. Despite its potential, some interactions, such as selecting and dragging files, moving files, and typing, are not feasible with this two-point model. Alternatives for these interactions were prototyped during the 'Design for VR' project, which will be discussed later in this document.

Fig. 4(g) : Dots being tested with a target user

2.5 Insights from Secondary Research

The projects and research papers that I read about accessibility, virtual reality, behaviour and gestures, helped me to get familiar with challanges and struggles associated to develop tools related to it. It would be important to note that it took them a long time and lot of research to come up with designs that work in the domain of accessibility in VR.

Initally I began this project with lot of hopes and expectations to do lot of things, which kept narrowing down further and further as I read and understood the area more. The key take away from the projects like Dots and seeingVR are as follows :

- Focus on fundamental interactions in a domain, and contextualise the interactions and then build on it.
- Make interactions as natural, familiar and intuitive as possible for the user.
- For the accessibility related interactions allow a room for adjustment and try to approach it from multiple lenses.
- When one is designing for disability, spectrum is very wide, one must contextualise and specify what kind of disability is being addressed in the project.
- Technical challanges may overpower the design while designing tools for accessibility.

- We expect user to understand and be comfortable with the solution very early. However, it is important to note that, it takes time to adapt to it.
- Intuitive gestures are not random, and they have purpose and are mostly derived from the existing actions and daily lives.
- Controllers are limiting in some sense and it requires lot of time to learn functions however they are highly accurate.

Keeping those key learnings in mind, I further started narrowing down my project from making interactions for accessibility in VR to One handed interactions for Sketching in VR and focused on eliminating controllers for sketching in VR which is a huge pain point for PwDs with LD.

3. Primary Research

Based on the feedback from the previous stage of the project, I started focusing on interactions that are only done by two hands and controllers in existing systems which are difficult and have no alternate ways to interact.

3.1 Sketching in VR

One area where interactions are complex and can be done using two hands and controllers majorly is Sketching or Modelling in VR. Gravity Sketch and Tilt Brush are two of widely used apps for modelling / sketching in VR. But there are a lot of limitations for people with locomotor disability in upper limbs as it requires them to use both the controllers very precisely. These interactions are very complex in nature and involve a lot of steps. Today, there are two major sketching apps widely used for VR which are : Gravity Sketch and Tilt Brush.

Fig. 5 (a, b) : Tilt Brush by Google and Gravity Sketch

3.2 Examining Gravity Sketch

For this project, we will examine Gravity Sketch on Meta Quest 2 to understand its interactions and identify their drawbacks. Most tasks are tied to specific controllers and can only be performed using them. The image below shows Gravity Sketch.

Fig. 5 (c) : Gravity Sketch for Meta Quest

Gravity Sketch

Gravity Sketch enables 3D modeling in VR using devices like Meta Quest, Rift, and HTC Vive, relying on two controllers for interaction. Both controllers are essential for most functions, making it nearly impossible to perform all tasks with one hand or controller, or with two-hand gestures. The flow of Gravity Sketch is shown below.

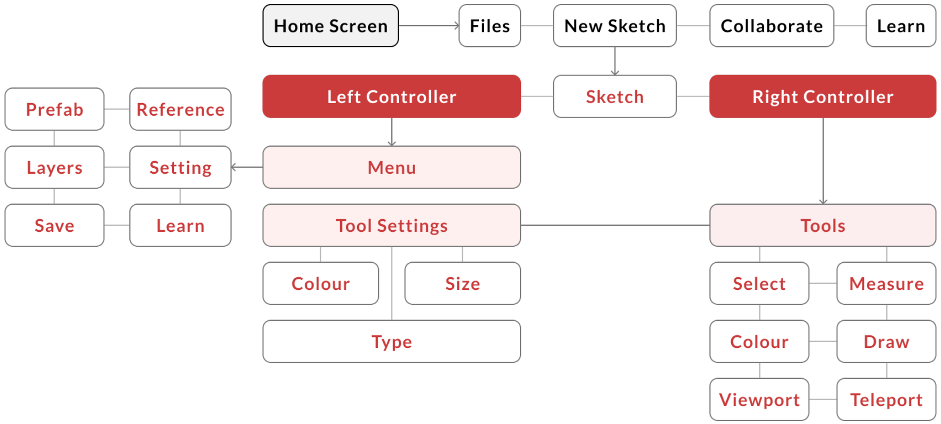


Fig. 5 (d) : Information Architecture, Interaction Flow & Structure of Gravity Sketch

3.3 Complex Interactions in G. Sketch

We broke down Gravity Sketch's workflow into small tasks and interactions, identifying eight major interactions. Five users (4M, 1F) evaluated each on four parameters. [Fig. 5(e)] shows the interactions and involved controllers. We will ideate for all interactions but only prototype and test those marked in red based on evaluation.

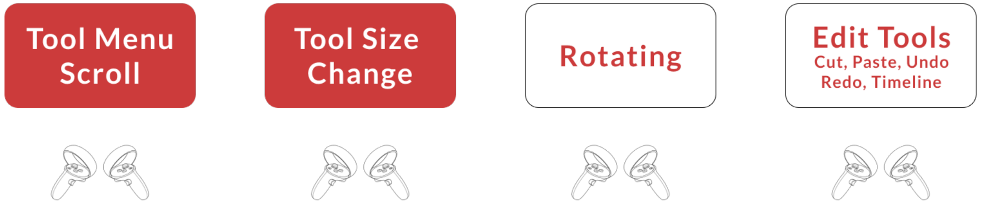


Fig. 5 (e) : Complex interactions with controllers in Gravity Sketch

Tool Selection

The tool selection in Gravity Sketch includes six tools: draw, color, select, measure, viewport, and teleport, accessible only with the right-hand controller. Switching controllers is not possible; users must press the tool button and navigate to the desired tool. Fig. 5(f)]

Controller: 2 | Steps: 1 | Discover : 4 | Essential : 5

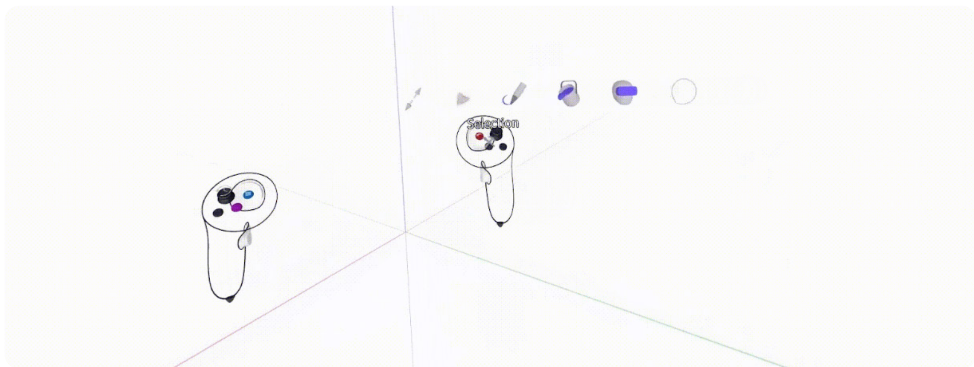


Fig. 5 (f) : Tool Selection in Gravity Sketch

Tool Menu Navigation

After selecting tools with the right controller, use the left controller to adjust tool parameters like size and type [Fig. 5(g)], while navigating with the right controller.

Controller: 2 | Steps: 2 | Discover : 4 | Essential : 5

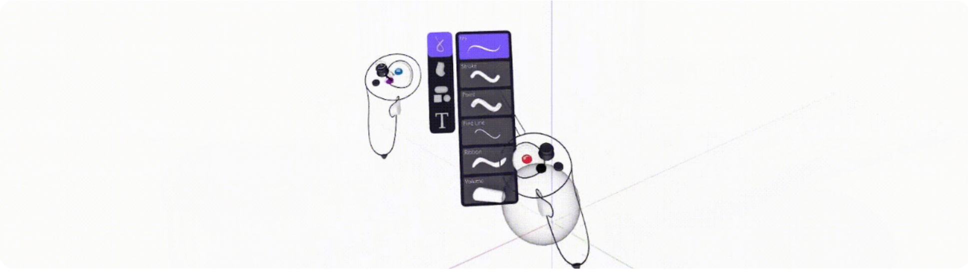


Fig. 5 (g) : Tool Menu Navigation in Gravity Sketch

Colour Change

With the drawing tool active, the right controller accesses the color palette or wheel, while the left controller selects the color. Quick color selection [Fig. 5(h)] is available on the bottom panel.

Controller: 2 | Steps: 2 | Discover : 3 | Essential : 5

Fig. 5 (h) : Colour Selection n in Gravity Sketch

Tool Size Change

You can adjust tooltip size by sliding the joystick on the right-hand controller up or down, or by using the tool menu.

Controller: 1 | Steps: 1 | Discover : 5 | Essential : 5

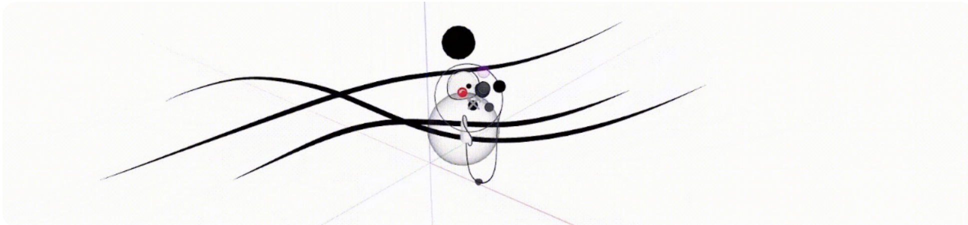


Fig. 5 (i) : Tool Size Change in Gravity Sketch

Move & Scale

To scale you need to hold an object from one point after selecting with one controller and then with another controller you need to scale the selected object.

Controller: 2 | Steps: 3 | Discover : 2 | Essential : 3

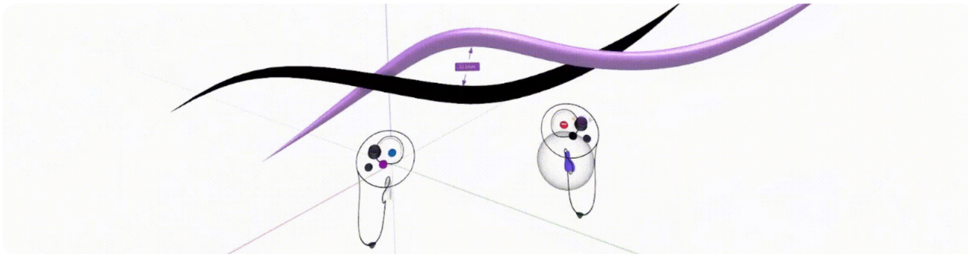


Fig. 5 (j) : Move & Scale in in Gravity Sketch

Rotate

Rotating is a two point interaction similar to scale interaction, where you select one point or axis around which you rotate and then you rotate with reference to that point through another point ie. controller.

Controller: 2 Steps: 3 Discover : 2 Essential : 3

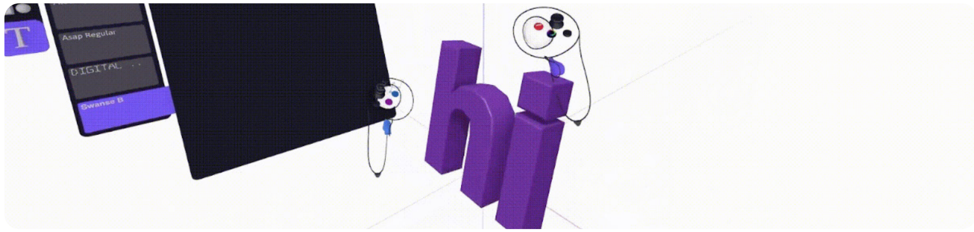


Fig. 5 (k) : Rotating in Gravity Sketch

Measure

Measure is also a two point interaction where you select two points that you want to measure distance between. This is right hand controller interaction where you keep holding the button in the controller.

Controller: 1 Steps: 2 Discover : 4 Essential : 2

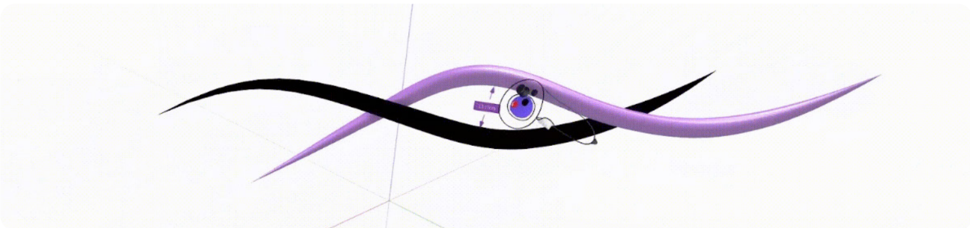


Fig. 5 (l) : Measuring in Gravity Sketch

Other Interactions : Select, Cut, Copy & Undo

This is a set of interactions which are performed using various gestures after selection of the object by using the controllers.

Controller: 2 Steps: 3 Discover : 3 Essential : 4

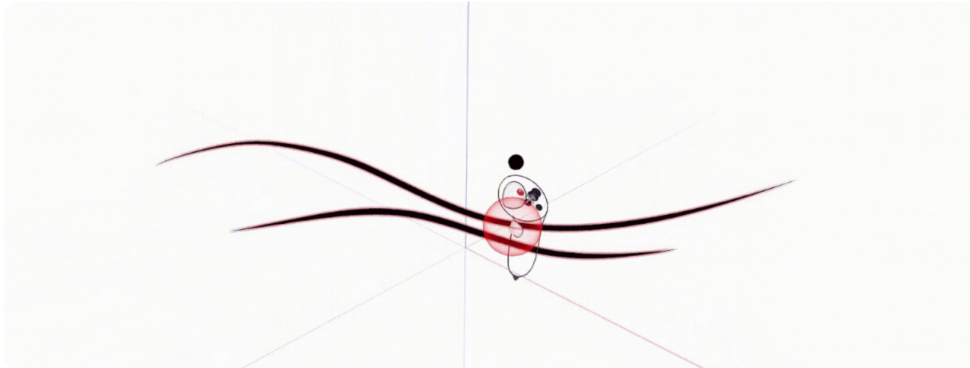


Fig. 5 (m) : Selecting in Gravity Sketch

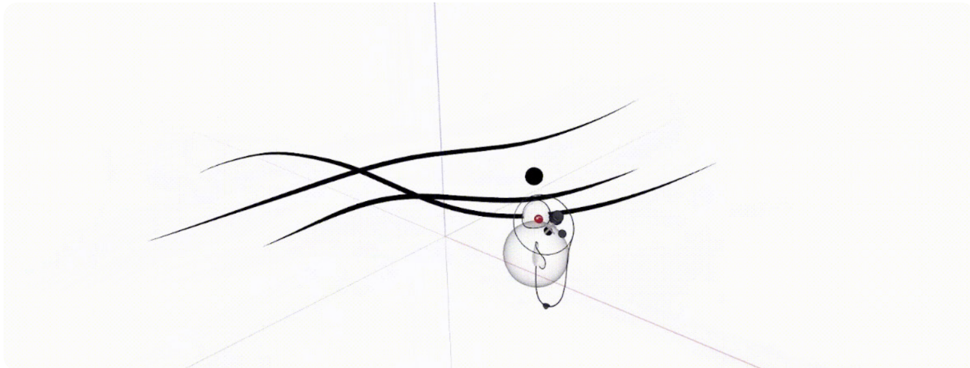


Fig. 5 (n) : Undo in Gravity Sketch

Evaluation Summary

Based on the testing and evaluation we can summarise the data as given below :

Task	Controllers	Steps	Discovery
Tool Selection	R	1	4/5
Tool Menu	L,R	2	4/5
Colour Selection	L,R	2	3/5
Tool Size Change	R	1	5/5
Move & Scale	L,R	~3	2/5
Rotate	L,R	~3	2/5
Measure	R	2	4/5
Copy-Paste-Undo-Redo	L,R	~3	3/5

3.4 Insights from Gravity Sketch

- Controller usage is complex and unintuitive, requiring a steep learning curve.
- Users accustomed to UI-based sketching benefit from knowing actions without deep navigation.
- Operating both controllers is challenging for those with limited or no use of one hand.
- Switching controllers by hitting them together is not ideal; tasks requiring both controllers remain difficult.
- A combination of gestures, poses, and UI elements could improve interaction, reducing gesture conflicts and fatigue.
- Exploration of interactions during the 'Design for VR' course informed ideas for non-controller interactions.

4. Designing for Sketching in VR

4.1 Early Experiments in Unity

During the ‘Design for VR’ course, we prototyped various one-handed VR interactions like scrolling, text selection, and moving with the Meta Quest Pro using Unity, in a project called ‘Fusion.’ At that time, I was exploring possibilities and had not yet focused on VR sketching.

Fig. 6 (a, b) : Unity and Meta Quest Pro

Scrolling

Currently scrolling in Quest is pinch and drag the finger, which is a complex interaction and may create discomfort as most other interactions include the same. On the other hand, we are used to using our mobile devices in a certain way to scroll and the position is very intuitive for one hand interaction. We used similar kind gestures to create interaction for the VR environment for scrolling.

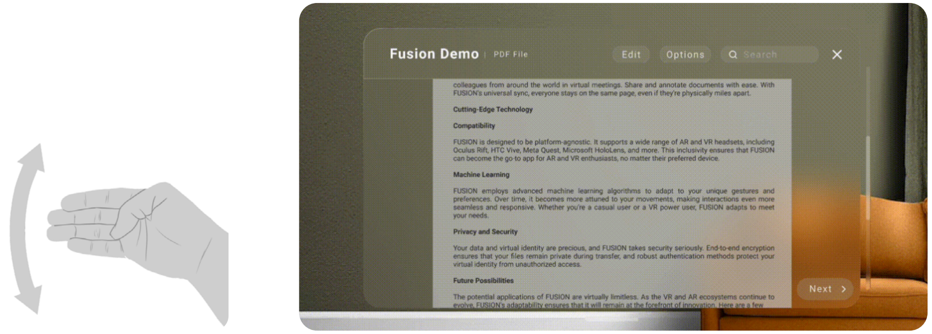


Fig. 6 (c, d) : Palm swipe gesture and scroll interaction

Selection

Selecting text typically requires using controllers and pressing buttons. To improve efficiency for those with locomotor disabilities, we opted for a one-handed gesture using two fingers to select text, mimicking the ‘I’ cursor shape used on desktops.

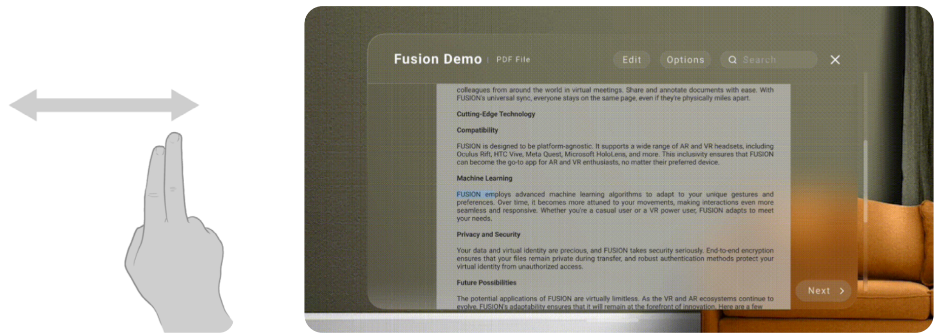


Fig. 6 (e, f) : Two finger swipe gesture and selection interaction

Moving Files

Oculus or Quest is basically an android device just like an android smartphone. Files are an important component of any device. However, there is no native file manager in Oculus/ Quest yet. Third party apps have no native gestures to do file management yet and most of them require controller or pinch gestures. Also, the apps are not optimised to run in VR yet. To move files, we designed and prototyped the grab and drop gesture in Unity for the project.

Fig. 6 (g, h) : Grab & Drop gesture and moving interaction

Insights and Learnings from Testing

We exhibited these interactions at the Design for VR exhibition at IDC as part of the course. Many people tested these interactions. We got multiple feedbacks on the interactions. Based on that, I have noted down a few insights on various aspects of the project as follows.

Fig. 6 (i, j) : Testing interactions at the exhibition

- The experience of those interactions could have been weaved into some kind of narrative or playful experience.
- There were slight inefficiencies and clashes in the default interactions and the one we designed. The colliders used in the design of the scroll interaction could have been optimised.
- The users were unable to select where they would begin selection and where they would end. It was due to technical glitch of the prototype.
- Grab and Drag interactions could have been designed better to snap better.
- The scale of the UI elements, the distance between user and interface and reachability were not accurately optimised which created problems while interacting.

4.2 Ideation

As there is complexity in interaction which excludes entire group of people, there is a need to design interactions that inuitive, adaptable and accessible. With controllers, that is being compromised. Now, we will discuss set of ideas of interactions for eleminating controllers. These interactions were designed on basis of paper read, literature studied and insights from the studies. The key ideas that govern interactions :

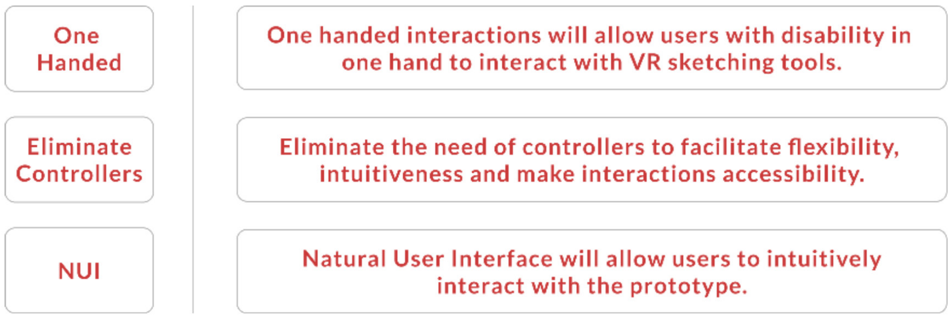


Fig. 7 (a) : Key Ideas governing the interactions

Translating Interactions

When translating controller-based interactions to non-controller, one-handed methods, the focus was on essential interactions such as tool selection, drawing, and color changes. Secondary interactions like move, scale, rotate, and measurement were considered later. The diagram summarizes final interactions and ideation.

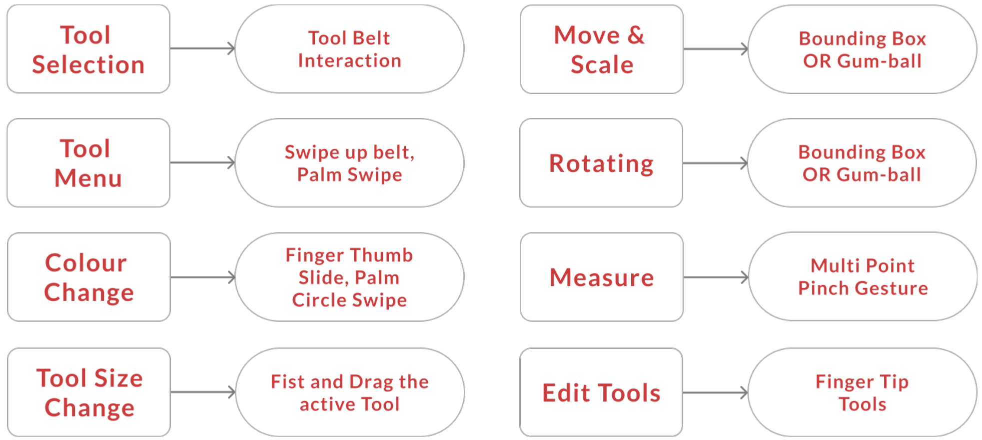


Fig. 7 (b) : Summary of translating interaction to eliminate controllers

Tool Selection and Drawing

This interaction must allow switching between tools ie. sketch, colour & material, select, measure, viewport and teleport. Below contains few interaction ideas in which it can be achieved.

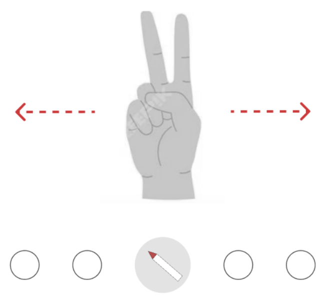


Fig. 7 (c) : Swipe to change tool

Idea 1 : In this idea, the user performs two finger pose to trigger the tool selection , and swipe to switch between tools while the pose is active.

This **idea was rejected** later and was not taken further as it was not intuitive and could be falsely activated.

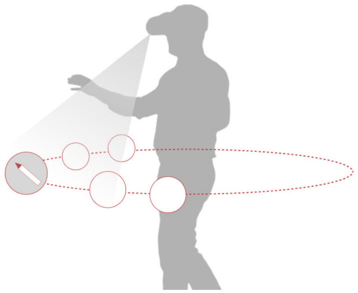


Fig. 7 (d) : Tool belt for tool selection

Idea 2 : Looking down will trigger a set of tools around the waist and one can grab a tool and activate it. Belt disappears as one lifts the head.

This **idea was taken further** as user does inuitively looks around, and this will prompt them to select tool.

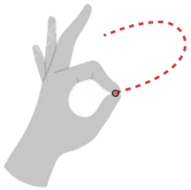


Fig. 7 (e) : Tool belt for tool selection

Drawing : Once the tool is selected one can start drawing in 3D space with pinch and drag/draw gesture.

This **idea was taken further** as this is inuitive.

Tool Menu Navigation

This menu helps to edit the tool and change the settings of the tool. For example, change the stroke style of the drawing tool. Currently it's done using two controllers simultaneously.

Idea 1 : In this idea, the user triggers the menu by looking at the palm, and navigates via swiping thumb on the palm. Users can lock the menu by closing the fist and pinching on the parameter to modify to select it.

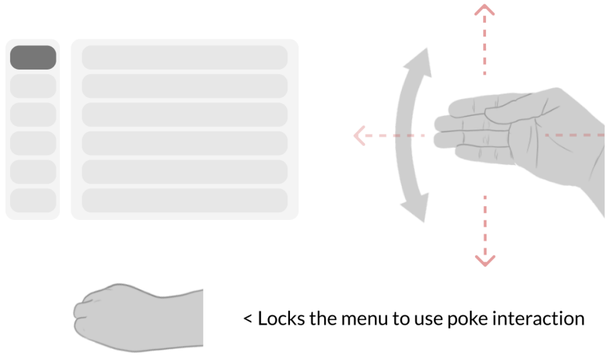


Fig. 7 (f) : Tool menu swipe navigation & lock

This interaction is inutive and novel. However, the **idea was not taken further** to the prototype stage due to technical complications while prototyping.

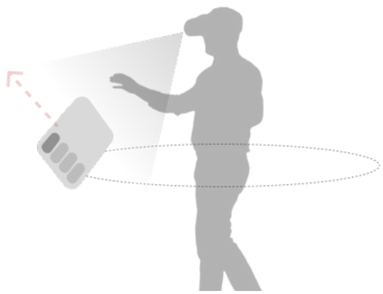


Fig. 7 (g) : Tool belt for tool selection

Idea 2 : In this idea, the user can swipe up with the palm near the belt to trigger the menu, one can pinch or poke the menu item to select and modify the parameters.

This **idea was not taken further** as it will involve each tool to be developed.

Colour Change

Color changing is crucial for VR sketching, and quick access to favorite colors is essential. Currently, selecting colors from the wheel or quick-selecting favorites requires using both controllers. Our ideations addressed these issues while examining Gravity Sketch.

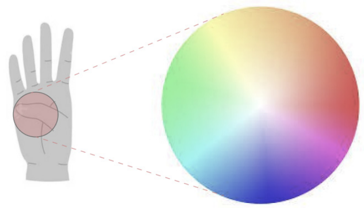


Fig. 7 (h) : Palm colour wheel

Idea 1 : With this interaction users can use thumb movement on the palm to select colour from colour wheel in VR and change the colour of tooltip.
This idea was taken further in a simplified way to choose desired colour from the colour wheel.

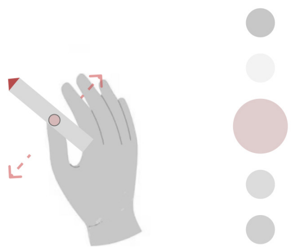


Fig. 7 (i) : Finger swipe colour switch

Idea 2 : With this interaction one can switch favourite colours while drawing. Users can swipe their thumb on the first finger to change the colour.
This idea was taken further as it was essential and novel while being technically feasible to develop.

Tooltip Size Change

After the colour, another essential feature that is important for sketching in VR is tooltip size change. Currently you can change it by using left hand controller's joystick and moving it up and down. There were two gestures that were ideated for this interaction/feature. Out of which one was taken further to prototype.

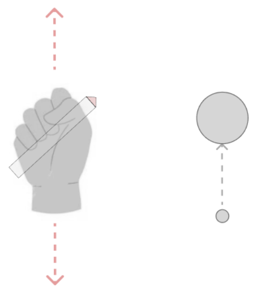


Fig. 7 (j) : Fist drag tooltip change

Idea 1 : One can change the size of the tooltip by closing the fist while the tool is active and moving fist up/ down and normal as you open fist.
This idea was taken further as it was essential and novel while being technically feasible to develop.

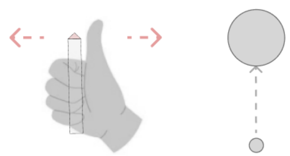


Fig. 7 (k) : Thumb swipe tootip change

Idea 2 : One can change the size of the tool or brush by moving their thumb up or down while holding tool. As you pinch again, it gets activated to draw.
This idea was not taken further as it may give false activation at times and it would not allow high range of sizes.

Secondary Interactions

All the interactions were primary and essential. Now, we will discuss ideation of the advanced interactions. These interactions were not taken to prototyping phase as developing those features efficiently was challanging and not feasible in the time period of the project. Hence, they are out of the scope of prototyping for this project.

Move, Scale and Rotate

Move, scale and rotate are important features for 3D modelling as well as sketching in VR. However the way VR enviorment handles it differs from the screen based interactions. Here attempt was to create similar experience as 3D modelling interface. However, it could be further improved if we dwell into it further.

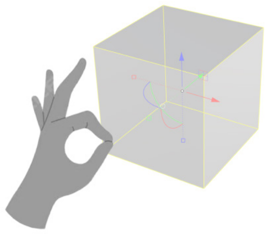


Fig. 7 (l) : Gumball

Idea 1 | Gumball : In this concept, the user triggers the gum-ball by double pinching and selecting an object. You can switch between, scale, rotate and move with UI Buttons and change the parameter by using the handles in an axis or center.

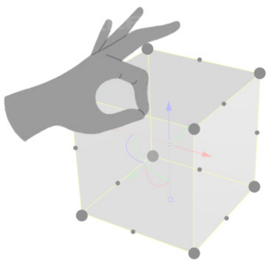


Fig. 7 (m) : Bounding Box

Idea 2 | Bounding Box : In this concept, a bounding box will be triggered by double pinching and selecting an object. It contains around 24 points that will appear in the bounding box edges. Using those points users can manipulate the object.

Measure

Measure comes handy when you are dealing with precise modelling and sketcching in 3D evenviornment and VR. However it is non-essential for the current project and prototype. If we were to conceptualise, the interaction would look something like as given below.

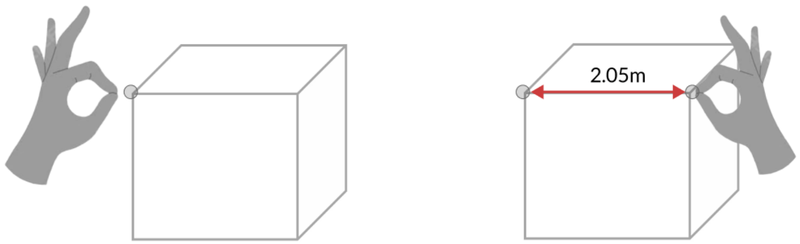


Fig. 7 (n) : Measure tool point selection

Users select this tool from the menu, assign two points to measure distance, and place them by pinching. The points can be relocated by pinching and dragging.

Edit Tools

This set of edit tools like copy, paste, undo, and redo is activated by looking at your palm which triggers buttons on four fingers as given in the diagram.

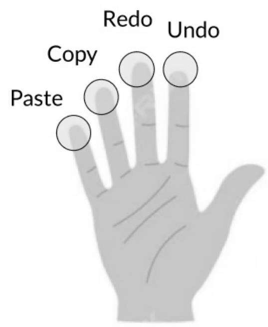


Fig. 7 (o) : Finger Buttons, Edit Tools

The tools ie. undo, redo, copy and paste which are frequently used can be activated as shown in the image and can be used by tapping thumb on the fingers with triggered button. The advantage of these interactions is that you get self-feedback on performing gestures.

4.3 Prototype

Challanges

This technology-heavy project required months of coding and development struggles due to my lack of prior experience with Unity and C#. Learning and problem-solving took time, and technical glitches caused some failures. Despite these challenges, the journey provided significant learning opportunities.

Prototyping in Unity for Oculus

The prototype was developed in Unity using C# for the Quest 2, incorporating libraries and packages like Oculus Integration SDK.

The entire process involved lot of back and forth, failures and learning. A typical workflow can be described through a diagram.

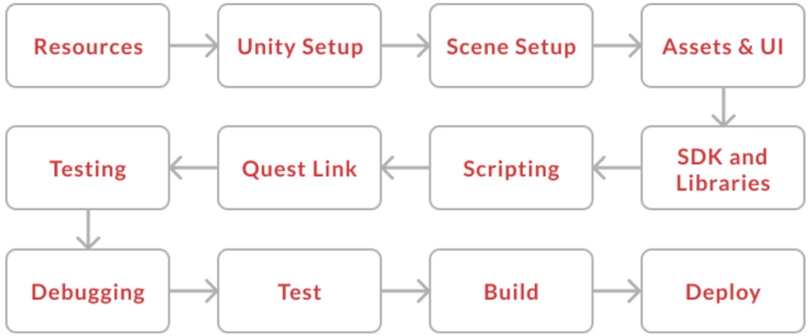


Fig. 8(a) : Unity Workflow

Further Exploration in Unity

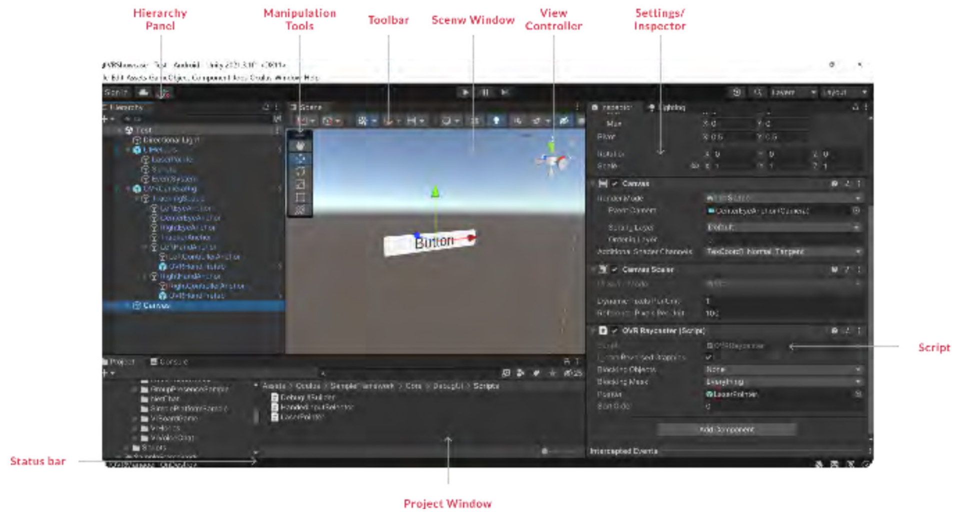


Fig. 8(b) : Unity Interface

The Unity Interface consists of five key regions: Hierarchy, Project Window, Scene Window, Toolbar, and Inspector, which govern user flow. Scripts can be assigned to components by dragging. The Hierarchy window shows game object layers and their parent-child relationships, with scripts on parent objects affecting child objects. Game objects, scripts, and assets are organized in the Project Window and added to the Scene as needed. The central top button plays the game, but edits can only be made in Scene mode.

Prototyping Each Interactions

The prototype consists of the following interactions as discussed earlier:

1. Draw [Pinch to Draw]

2. Quick Switch Colour [Swipe Thumb on Finger]

3. Tool Size Change [Hold and drag to change Thickness]

4. Tool Belt [Pick tool by looking down]

5. Colour Wheel [Palm Swipe]

Each interaction was developed seperately initially and entire prototype was divided in small chunks. The interactions were not developed in the sequence of their use. Lets dwell into how I developed each interaction in brief.

1. Draw

The interaction works using draw function in C# script. The collider assigned to this script acts as a tip and hence we can draw using it in unity. This uses grabbable component from oculus integration package. We have assigned this to be used with both the hands. In this attempt we tried to make a pen/tool to draw using simple cylinder to experiment with this interaction. We used VS Code studio for scripting. However, one can use any text program also.

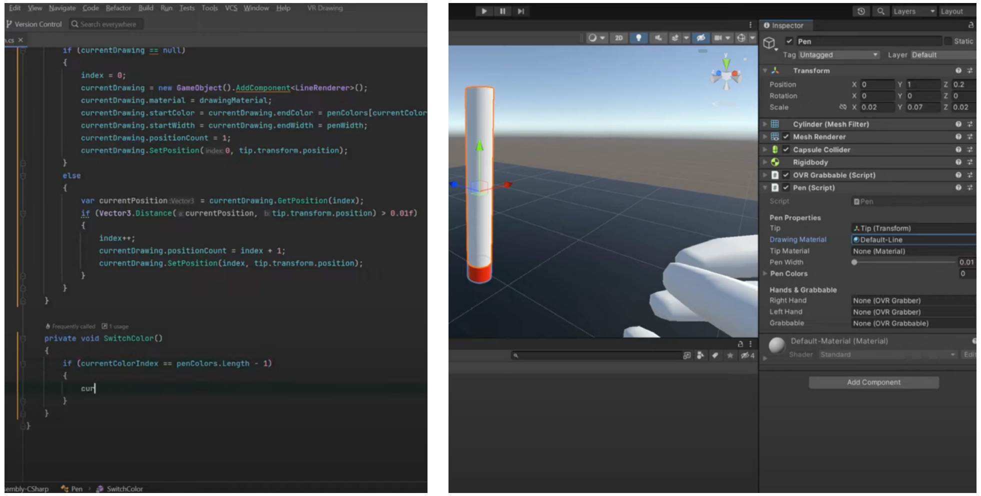


Fig. 8(b) : C# Scripting in VS Code and Unity during development of draw tool

In first few attempts this did not work well, and the grabbable component had to be troubleshooted. Later when we were able to resolve the issues, we tested it on Quest 2 device via Quest Link.

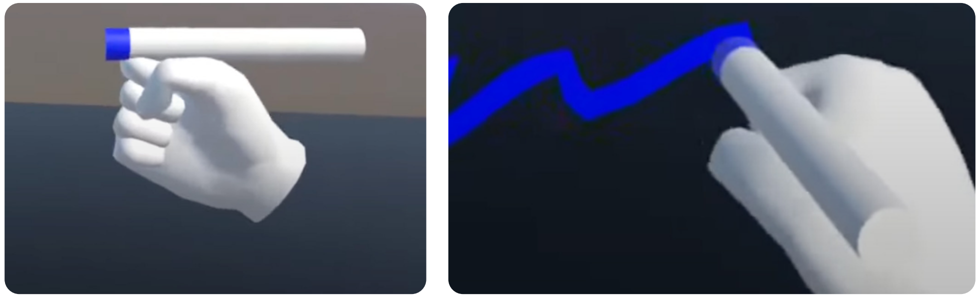


Fig. 8(c) : Snapshot of testing from Quest 2 using draw function

2. Quick Colour Switch

Building on our previous tool, this interaction enables color switching with a snap gesture (thumb on finger), mimicking a multi-color pen. This intuitive VR feature eliminates the need to access the color wheel, making it a convenient and playful addition.

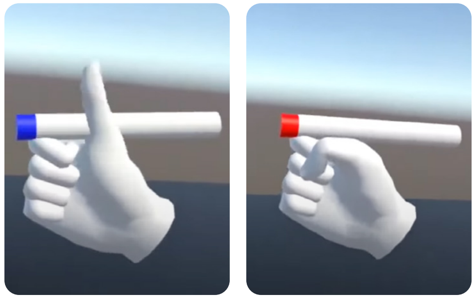


Fig. 8(d) : Colour Switching

Fig. 8(e) : JetPen MultiColoured

As we snap the index number changes as written in the script and colour associated with it appears.

3. Tool Size Change

Further adding and experimenting with the previous tool we made, we played with previous script and triggered interaction of changing the tooltip size by sliding. For this we had to introduce new gesture to the C# script and change the assigned index number or size with the gesture when its practiced.

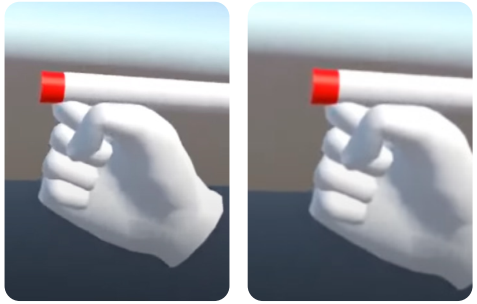


Fig. 8(f) : Tooltip Size Change

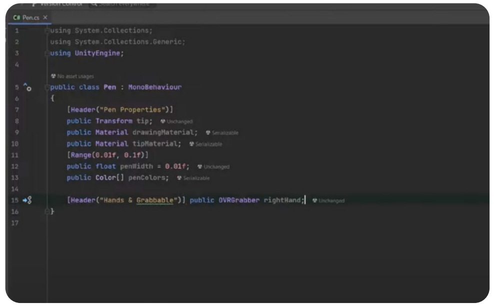


Fig. 8(g) : Tooltip Scripting in C#

4. Tool Belt

At this stage, we created new assets for the final prototype, including Undo, Multi-Coloured Pen, Brush, Eraser, and Redo. Users can select either the Pen or Brush to start drawing, adjust tool tip size, and choose colors from the brush palette. The assets are shown below.

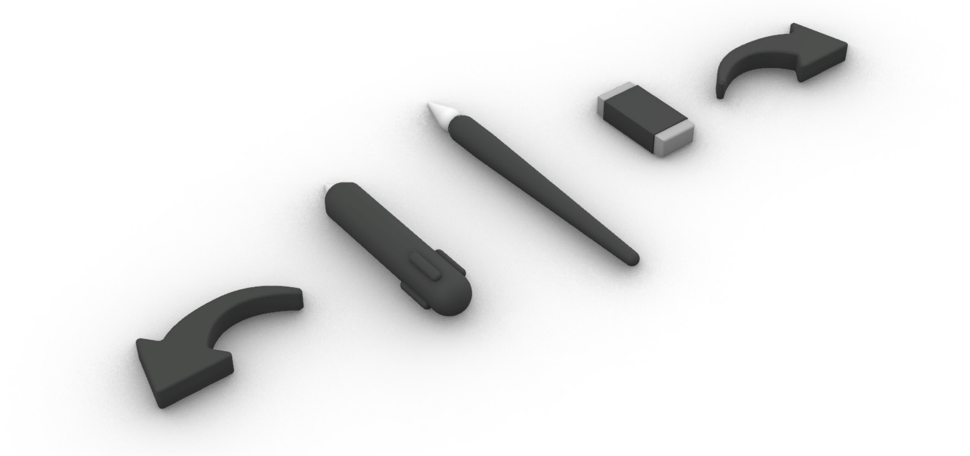


Fig. 8(h) : Raw models of the tools assets

These tools were made a parent of an empty object which was parent of the camera / headset. Thus it moved with the headset. To make it disappear and re-appear while we look down towards it, we used raycast and when the rays are casted on the parent object, it appears and we can select it.

Fig. 8(i) : Placing tools in the tool belt (Non-raycast)

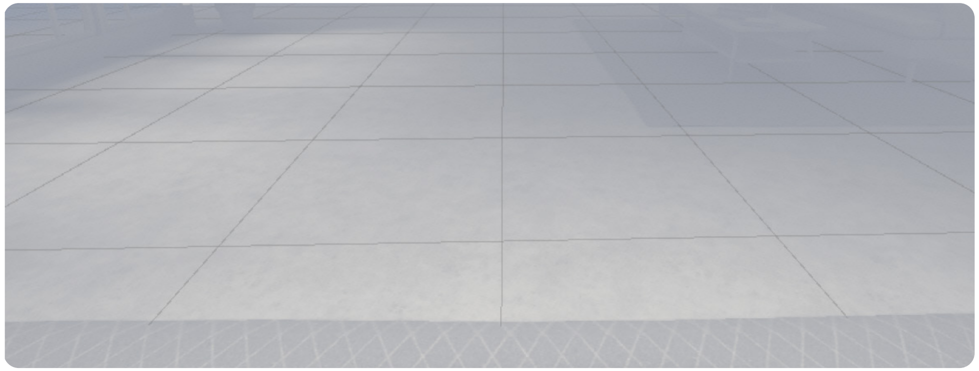


Fig. 8(j) : Toolbelt disappears while looking ahead

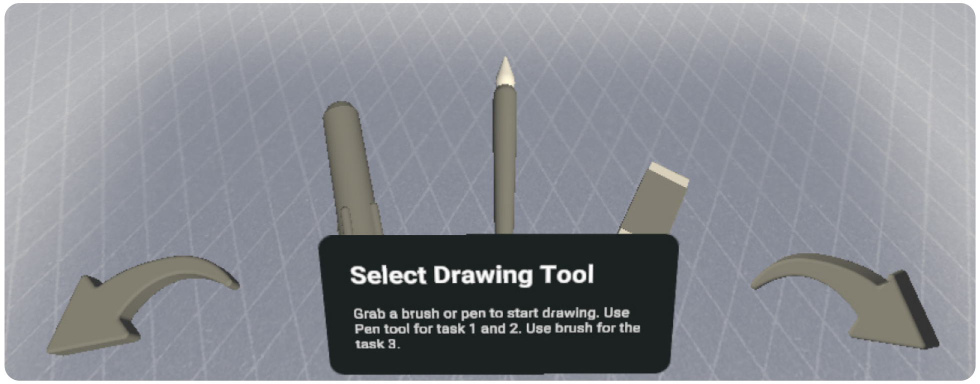


Fig. 8(k) : Toolbelt while looking down on with prompt

5. Colour Wheel

In this interaction colour wheel act as hand menu. It appears as we gaze at palm and it disappears as we turn hand. The navigation on the wheel happens through moving thumb on the palm. We used two scripts to create this interaction, one handles the navgation, and one creates a colourwheel in UI Canvas.

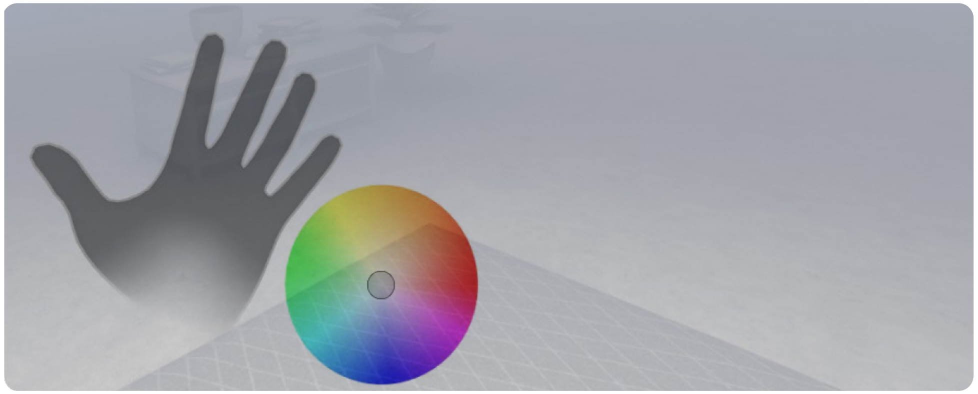


Fig. 8(l) : Colour wheel while looking at the palm

5. Evaluation

Evaluation Plan

To evaluate the suggested interactions, user testing or usability testing will be conducted across three phases. Each participant will receive a reference image in every phase and utilized the prototype to complete drawing tasks. The intricacy of drawings escalated with each successive phase, prompting participants to share their feedback (qualitative study). Subsequent to this **within study**'s feedback, the project will facilitate discussions on interaction techniques and suggested refinements based on the received insights. The diagram suggests and summarises the evaluation process.

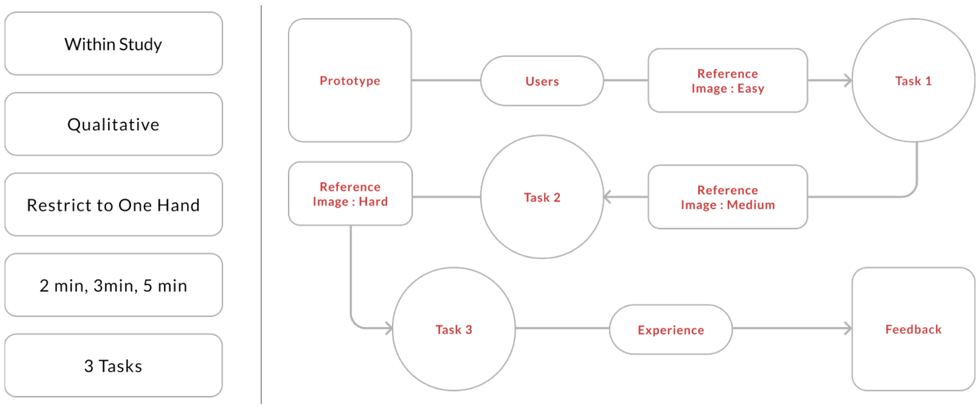


Fig. 9 (a) : The process of user testing

Data Collection

As we established earlier that this is primarily qualitative study, we prepared a questionaire to collect feedback from the users. We will also measure overall satisfaction and time taken and progress of users over time, to test if we could find some important insights out of it. The questionaire involved four types of questions as follows:

Experience : Describe your experience while completing the drawing tasks in each phase. Were the tasks clear and understandable? Why or why not?

Challanges : Did you encounter any difficulties or challenges during the interaction with the prototype? Were there specific features or interactions that were confusing or hard to use?

Suggestions : Do you have any recommendations or features you would like to see added or modified?

Overall Satisfaction (Likert) : On a scale of 1 to 5, how satisfied were you with your overall experience using the prototype? (1 being very dissatisfied, 5 being very satisfied)

The data was gathered in a google sheet in a tabular format. The feedbacks would be discussed and analysed in the discussions section of this report.

Experience

Describe your experience while completing the drawing tasks in each phase. Were the tasks clear and understandable? Why or why not?

Challanges

Did you encounter any challenges during the interaction with the prototype? Were there any features that were confusing or hard to use?

Suggestions

Do you have any recommendations or features you would like to see added or modified?

Overall Rating

On a scale of 1 to 5, how satisfied were you with your overall experience using the prototype? (1 being dissatisfied, 5 satisfied.)

Fig. 9 (b) : Evaluation parameters

Tasks

Fig. 9 (c) : Task 1, Select draw tool & draw a flower

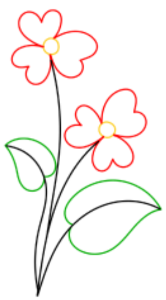


Fig. 9 (d) : Task 2, Select draw tool & draw a flower using different colours

Fig. 9 (e) : Task 3, Select draw tool, draw a flower with colours & add details using thinner tip

Each participant will be given three tasks and one image to refer in tasks. At each subsequent task image gets more complicated. We took simple task of drawing a flower as not all participants were fluent at drawing. The aim here was to test different features of the prototype.

Participants (Pilot)

We conducted a pilot study with six participants (four males, two females, aged 20 to 31), assigning them three tasks. All were able-bodied, using only one hand for the test. Additionally, I tested it myself as I have a locomotor disability in one hand. Most participants had not used Gravity Sketch before but were familiar with other modeling or sketching software.

Setup and Testing

The setup consisted a Meta Quest 2 device connected to MSI Windows Laptop with Unity running on it. The prototype ran on Quest 2 via unity. Before each test, the prototype was calibrated and then given to the participants. Tests were done in the The partcipants were explained the task before each task. Maximum time alloted to each task was 2 minutes, 3 minutes and 5 minutes respectively.

Insights from Pilot

The users feedback ranged from positive to critical. The prototype had many glitches. However, some interactions were fun to use for the participants. The participant feedback table is given below, based on the questions we asked. Overall, partcipants enjoyed quick switch colour and drawing with it and found tool belt to be helpful. Participant felt more comfortable drawing by the third task, even though complexity was increased. However, they strugged with understanding tool size change interaction. The datasheet from pilot (and self evaluation) is attached here : https://docs.google.com/spreadsheets/d/1pJaiQrvzPNzHkFxsKw2yA7E3707K5Ekm_ThgZKzU5lk/edit?usp=sharing

Overall, we can conclude the feedback of the pilot and self evaluation as follows :

Experience: Participants generally found the tasks clear and fun. The pen interaction was well-received, providing a natural drawing experience.

Quick Color Switch: Quick color switching was a highlighted feature, enhancing the variety and creativity in the drawings.

Brush Size Adjustment: Brush size adjustment presented initial challenges for some participants. Sensitivity of brush size adjustment was noted as an aspect to consider for improvement.

Recommendations:

Participants expressed the need for a more intuitive interface for brush size adjustment. Some participants recommended additional features for enhanced functionalities.

Overall Satisfaction:

The overall satisfaction ratings ranged from 3 to 4, indicating a generally positive experience.

6. Future Work

The feedback and suggestions gathered from the study open up exciting possibilities for the future of this VR sketcing prototype. **Iterative refinement** is a natural next step, addressing the challenges highlighted by users, particularly the sensitivity of brush size adjustment. I would like to implement a more refined interface and additional features based on user recommendations will contribute to a more polished and user-friendly experience.

I would like to **extend user testing** with diverse participant groups. That will provide a more comprehensive understanding of the prototype's usability across different demographics. This exploration could involve individuals with varying levels of VR experience, age groups, and cultural backgrounds.

It would also be **intruiging to explore other applications** of these kind of interactions like in areas such as **education, productivity, media,** etc. Researching further into the **potential of natural user interfaces** (NUIs) presents an opportunity to identify and implement new gestures that align seamlessly with users' natural behaviors. This could enhance the intuitiveness of interactions within the VR environment.

7. Reflections

Reflecting on this project, I realized the complexity of designing for accessibility and the importance of iterative processes. My initial expectations were high, leading to challenges, particularly technical ones. Initially, my focus was broad, targeting VR accessibility and interactions. Narrowing down to sketching interactions allowed for better ideas and deeper exploration.

Attempting to create a full-fledged one-handed VR sketching system like Gravity Sketch was overly ambitious given the technical challenges. Studying foundational research helped me focus on essential interactions and develop novel solutions. Observing users interact with natural gestures highlighted the potential of natural user interfaces (NUIs) for immersive environments.

Challenges in brush size adjustment emphasized the need for a user-friendly interface and the importance of adaptability to user feedback. Despite heavy struggles, especially with technical issues, this experience taught me resilience and perseverance, which, though sometimes frustrating, ultimately drove my progress.

9. References

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Fig. 4(a-e): Screenshots from Seeing VR, https://www.microsoft.com/en-us/research/uploads/prod/2019/01/SeeingVRchi2019.pdf

Fig. 4(f) : Two point system used in the Dots, https://dl.acm.org/doi/10.1145/3406324.3410715

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Fig. 5(a) : Tilt Brush by Google, https://www.tiltbrush.com/

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Fig. 5(c) : Gravity Sketch for Meta Quest, https://www.gravitysketch.com/blog/updates/your-first-sketch-in-gravity-sketch/

Fig. 5(f) : Tool Selection in Gravity Sketch, https://www.youtube.com/watch?v=mpKLKzHsK74&list=PLdcetkoP2x8S_1ijpvcLuds0s9hs0TIuC&index=6

Fig. 5(g) : Tool Menu Navigation in Gravity Sketch, https://www.youtube.com/watch?v=j28ZDnf7VFE&list=PLdcetkoP2x8S_1ijpvcLuds0s9hs0TIuC&index=3

Fig. 5(h) : https://www.youtube.com/watch?v=N5A2NZHGZ5E&list=PLdcetkoP2x8S_1ijpvcLuds0s9hs0TIuC&index=4

Fig. 5(i) : Tool Size Change in Gravity Sketch, https://www.youtube.com/watch?v=j28ZDnf7VFE&list=PLdcetkoP2x8S_1ijpvcLuds0s9hs0TIuC&index=3

Fig. 5(j) : Move & Scale in in Gravity Sketch, https://www.youtube.com/watch?v=2dc-AQRIjjU

Fig. 5(k) : Rotating in Gravity Sketch, https://www.youtube.com/watch?v=tMKrYSBAtVo&list=PLdcetkoP2x8S_1ijpvcLuds0s9hs0TIuC&index=2

Fig. 5(l) : Measuring in Gravity Sketch, https://www.youtube.com/watch?v=tMKrYSBAtVo&list=PLdcetkoP2x8S_1ijpvcLuds0s9hs0TIuC&index=2

Fig. 5(m) : Selecting in Gravity Sketch, https://www.youtube.com/watch?v=mpKLKzHsK74&list=PLdcetkoP2x8S_1ijpvcLuds0s9hs0TIuC&index=5

Fig. 5(n) : Undo in Gravity Sketch, https://www.youtube.com/watch?v=mpKLKzHsK74&list=PLdcetkoP2x8S_1ijpvcLuds0s9hs0TIuC&index=5

Fig. 6 (a) : Unity, https://1000logos.net/wp-content/uploads/2021/10/Unity-logo.png

Fig. 6 (b) : Meta Quest Pro, https://www.gamesindustry.biz/meta-quest-pro-headset-announced-launching-october-25

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