

The Alchemist: A Gesture-Based 3D User Interface for Engaging Arithmetic Calculations

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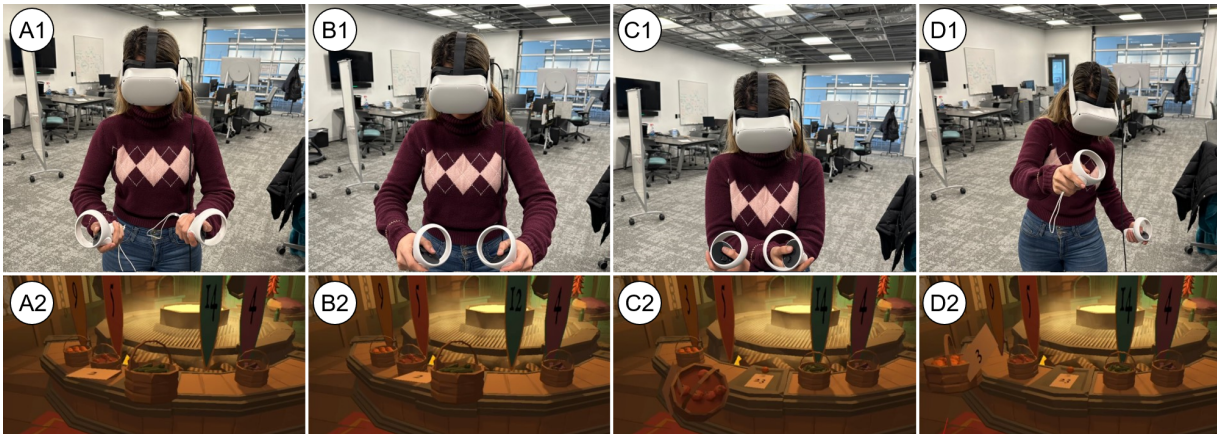


Figure 1: Operator gestures in the real world and within the virtual environment: (A1-2) Controller separation subtraction gesture. (B1-B2) Controller merge addition gesture. (C1-C2) Controller cross multiplication gesture. (D1-D2) Controller slice division gesture.

ABSTRACT

This paper presents our solution to the IEEE VR 2024 3DUI contest. We present *The Alchemist*, a VR experience tailored to aid children in practicing and mastering the four fundamental mathematical operators. In *The Alchemist*, players embark on a fantastical journey where they must prepare three potions to break a malevolent curse imprisoning the Gobbler kingdom. Our contributions include the development of a novel number input interface, Pinwheel, an extension of PizzaText [7], as well as four novel gestures, each corresponding to a distinct mathematical operator, designed to assist children in retaining practice with these operations. Preliminary tests indicate that Pinwheel and the four associated gestures facilitate the quick and efficient execution of mathematical operations.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual reality; Human-centered computing—Human computer interaction (HCI)—Interaction techniques

1 INTRODUCTION

Children often struggle to engage with difficult or confusing topics, such as mathematics. When teaching such topics, interactive tools and experiences should be explored to keep children motivated to learn new content that would otherwise lose their attention quickly. According to Anobile et al., the effective learning of mathematics is directly correlated with sustaining children’s attention visually [1]. In keeping with this idea, we developed *The Alchemist*, an interactive embodied experience that allows children to practice the four basic math operators in a fantastical adventure.

Text and number entry in Virtual Reality (VR) poses challenges for fidelity and immersion. Current input methods, like distally pointing and selecting characters, become cumbersome and time-consuming for large amounts of characters. A variety of methods have been tested for number input in VR, such as utilizing tracked gloves [3], controllers or a numpad [4]. While these input methods worked and were adequate for the technology of the time, there is still room for improvement.

Commercial games such as Prisms¹ and Math World² highlight the significant impact of VR in children’s learning of mathematics. While the interactivity [5] and gamification [6] of the immersive experience aids the children in quickly solving problems, the gesture-based solutions guide them towards a better understanding of concepts behind the problems [2]. We bring them together in a gesture-based embodied experience for children, *The Alchemist*.

In *The Alchemist*, users input numbers using a new interface called Pinwheel. Pinwheel allows users to quickly input numbers by flicking the joystick on either controller. In addition, fun gestures have been developed for each of the four mathematic operators that allow kids to quickly perform math operations in an engaging way while also promoting learning.

2 DESIGN PROCESS

Our design process began with weekly team meetings in which we defined our target calculation capabilities. We focused on creating an experience tailored to facilitate mathematical operations using the four basic mathematical operators via gestures. Additionally, we designed and implemented a number input method using a joystick to select numbers for operations. The final program was built using Unity and the OpenXR framework to support multiple head-worn displays.

¹<https://www.prismsvr.com/get-prisms>

²<https://skillprepare.com/math-world-vr/amp/>

3 STORY AND GAMEPLAY

The narrative unfolds within the Gobbler Kingdom, where the once vibrant and joyous citizens now grapple with a malevolent curse. This mystical affliction has cast a shadow over the kingdom, robbing its people of sight, hearing, and speech. Summoned by the Gobbler King to break the curse, the player, acting as the Supreme Alchemist, embarks on an extensive journey within their laboratory. After months of experimentation, three potion recipes have been discovered, each tailored to restore one of the senses affected by the curse. To concoct the potions, the player follows the unique recipes, adjusting the amount of ingredients within their available inventory through various mathematical operations, and then cooking them together to generate each potion.

4 INTERACTION TECHNIQUE(S)

In each recipe, users aim to acquire the correct quantity of each ingredient, which involves executing multiple mathematical operations. Each operation requires the utilization of both a basket of ingredients and a number pad object. Users must decide on the operation to perform and input a value on the number pad, which functions as one of the terms in the operation, to achieve the accurate amount of the ingredient in the basket. For example, if a basket holds six carrots, and the recipe requires three carrots, users can input “3” on the number pad and execute a subtraction or input “2” and perform a division. Both methods result in three carrots remaining in the basket. Each basket is pre-set with a specific quantity according to the current recipe, ensuring users are required to perform operations to achieve the correct amount. Executing operations entails specific gestures while holding the basket and the number pad. For inputting digits into the number pad, users engage with a number wheel. Subsequent sections will provide detailed information on both operations gestures and interactions with the number wheel.

4.1 Number Input

We developed a circular interface for numeric input named Pinwheel, featuring a 2D wheel divided into ten segments corresponding to the numbers 0 to 9. Users interact by manipulating the joystick on either controller to choose their desired number. Upon joystick activation, its position is tracked as a vector from the wheel’s center. As the wheel is divided into 10 sections of 36 degrees each, the selected number is determined by dividing the resulting angle by 36 and rounding down to the nearest whole number. The currently selected number is highlighted in red throughout the interaction and, upon joystick release, seamlessly added to a number pad for later use in operations. Deleting the last number added is achieved by pressing the primary button (A/X) on either controller. Our interface draws inspiration from the text entry technique called PizzaText [7]. The elegance of our approach, however, lies in its simplicity of selection. While PizzaText is designed for text entry with 26 characters, requiring progressive refinement after an initial group selection, we offer a direct, one-step selection for each digit.

4.2 Operator Gestures

We have designed and implemented different “gestures” for each of the four basic mathematical operations: addition, subtraction, multiplication, and division. For all interactions, users must distally point the ray extending from their controller at objects in the environment and pull the grip on either controller to pick up objects. The *addition* operation is performed when both objects are released while touching one another. Moving an ingredient basket in contact with the number pad and then releasing the grip combines the two values, adding the number pad’s quantity to the basket. *Subtraction* is characterized by moving two objects into contact and then separating them without releasing the trigger. In this process, the basket’s value decreases by the number pad’s value. *Multiplication* is triggered when users cross their arms, forming an X parallel to the

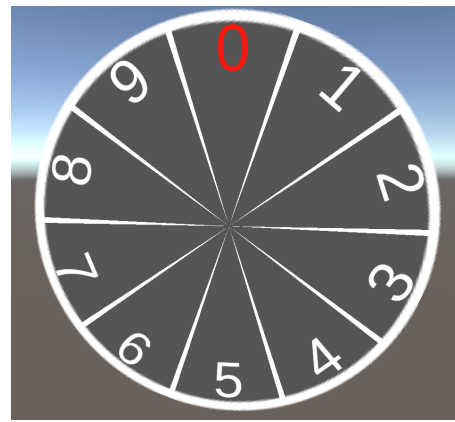


Figure 2: Pinwheel user interface

ground plane, while holding both objects. The value on the number pad then multiplies the ingredients in the basket. For the *division* operation, users grab both objects, release one to float (the ingredient basket), and then perform a “slash” gesture by striking the floating basket with the Magical Parchment. This divides the ingredients in the basket by the number pad’s value.

5 CONCLUSION

We have developed an innovative and captivating VR experience that incorporates gamification, utilizing novel 3D interaction techniques tailored for number entry and fraction operations. Our primary objective is to enhance the understandability and desirability of learning math and fraction operations among K-9 students. Our proposed new interaction methods for mathematical operations prioritize intuitiveness, ease of learning, and simplicity of execution. Additionally, we advocate for improved visualizations for fraction operations, aiming to facilitate a clearer understanding of these concepts. Furthermore, we introduce Pinwheel, a novel 3D interaction technique designed to enhance number entry. This technique is faster and easier to perform, remember, and learn, contributing to an enriched and efficient learning experience for kids.

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