Gaze-Supported 3D Object Manipulation in Virtual Reality

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眼球追踪技术支持下的VR虚拟物体操作方法

Background

XR & 3D User Interfaces

Virtual reality (VR) technologies, or immersive technologies in general, represent a significant paradigm shift from the traditional PC-based interaction by putting users "into" the digital content.

In those 3D interaction scenarios, traditional interfaces (e.g., based on mouse and keyboard input for desktops) are no longer adequate; for emerging 3D VEs to be productive and useful, it is crucial to design new forms of interaction.

Background

Mid-Air Input & Interfaces

Mid-air interaction is currently the main form for users to interact with objects in VR----Users control a virtual hand or a ray to select, manipulate, and interact with virtual objects.

While these mid-air interfaces can be helpful and intuitive for manipulating 3D content, they are identified by previous literature to be inefficient, imprecise, and fatiguing.

For instance, the Raycasting technique is notoriously inadequate for selecting tiny or distant targets due to hand tremor.

RayCasting


Virtual Hand

Theme

Improve Mid-Air Input in 3D User Interaction

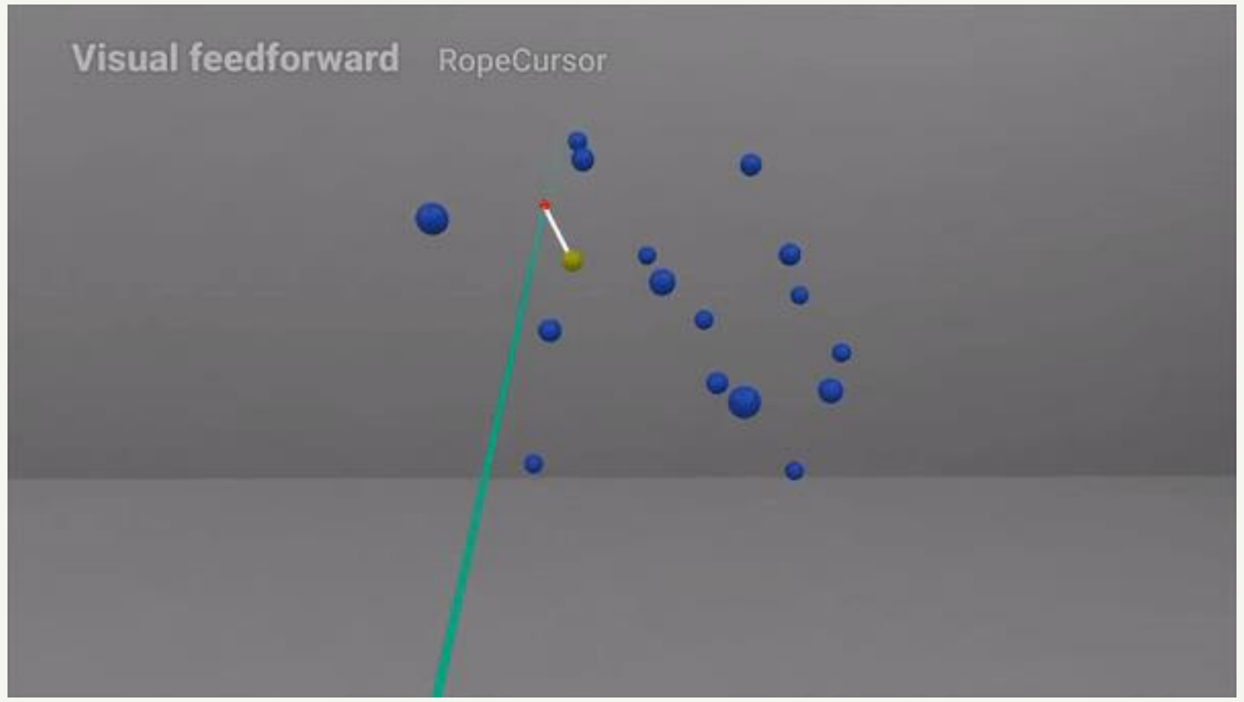
Enhancement Techniques

New designs based on existing techniques which aim to improve capability and efficiency.

Example: Interaction Technique

MagicBall+ and GravityZone+ [Yu et al. 2020]

RopeCursor [Baloup et al. 2019]



Theme

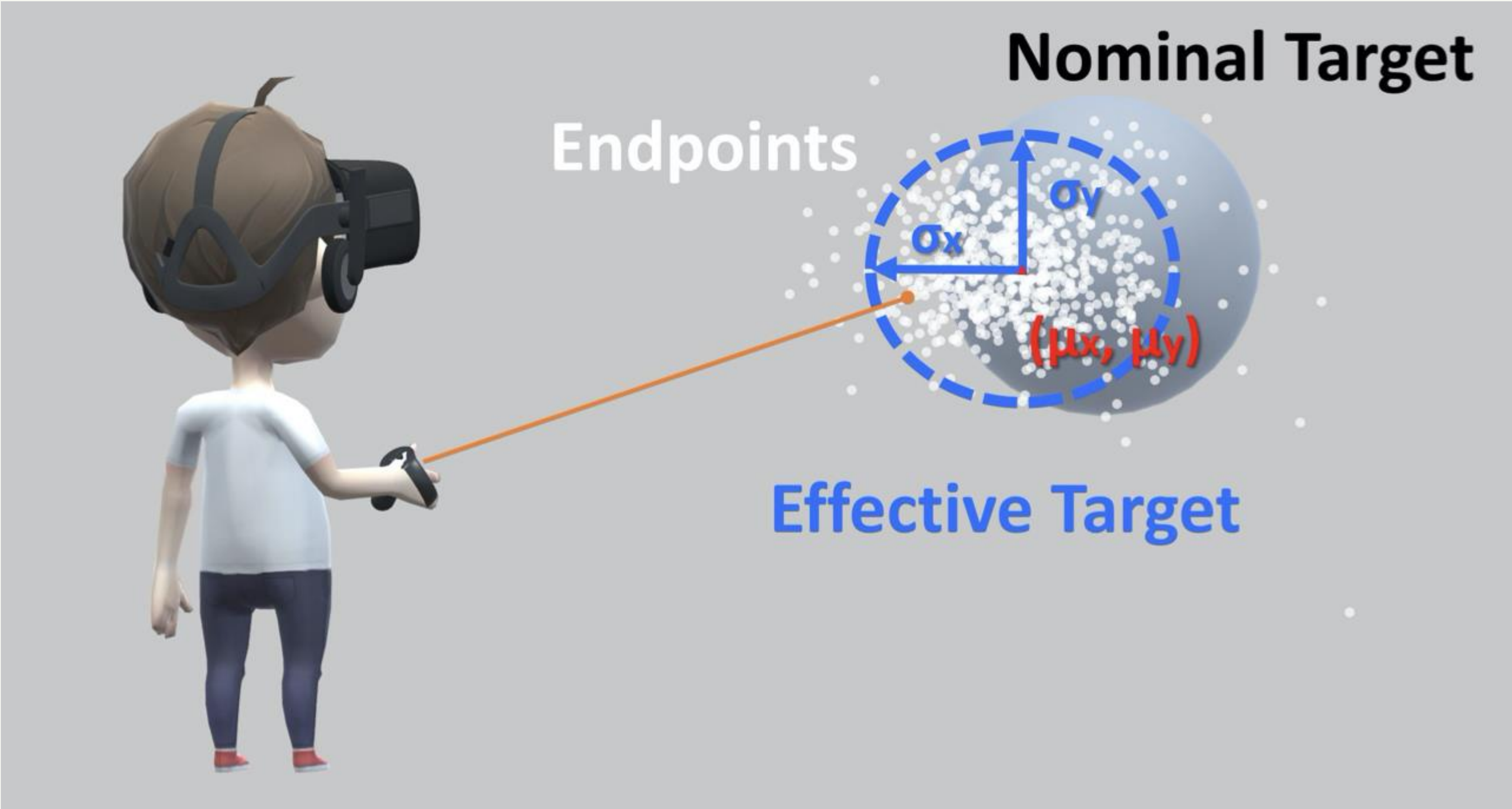
Improve Mid-Air Input in 3D User Interaction

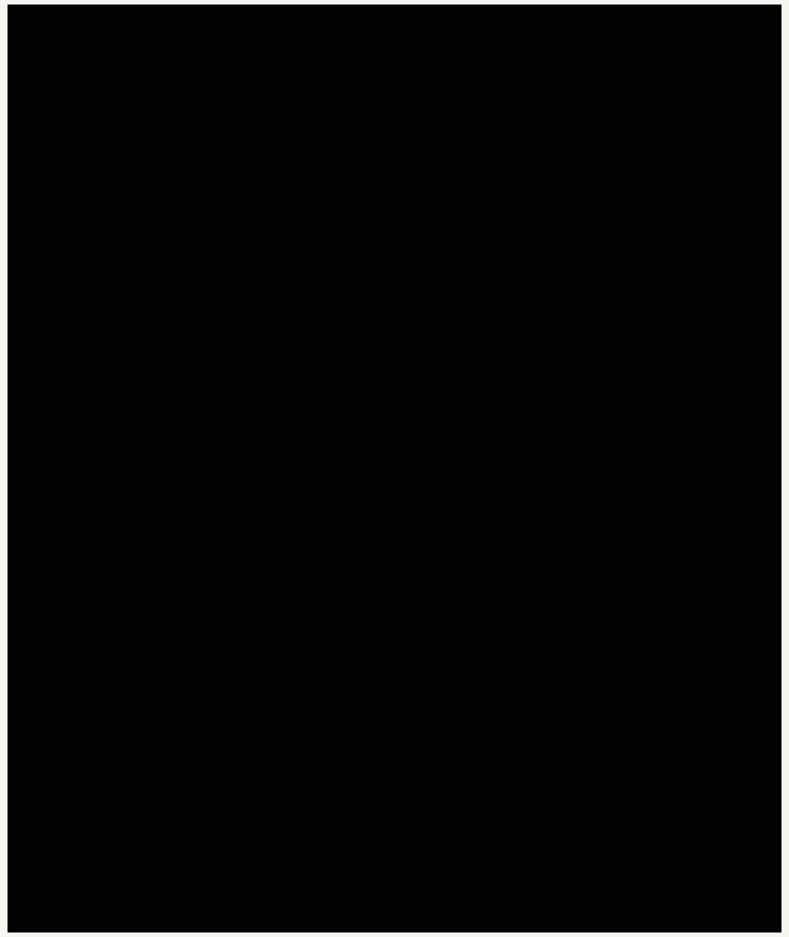
Enhancement Techniques
New designs based on existing techniques which aim to improve capability and efficiency.

Computational Models
Understand/Model user behavior and enable efficient and robust interactions in VR through predictive models.

Example: Computational Model

EDModel





Theme

Improve Mid-Air Input in 3D User Interaction

Enhancement Techniques
New designs based on existing techniques which aim to improve capability and efficiency.

Computational Models
Understand/Model user behavior and enable efficient and robust interactions in VR through predictive models.

Multimodal Interfaces
Incorporate other input modalities (e.g., gaze, smartphones) into the mid-air workflow to make more effective interaction.

Gaze-Supported Object Manipulation

Research Goal

Q1. *Whether* the incorporation of gaze input can benefit the hand manipulation process in VR

Q2. *How* gaze input should be combined with hand input for convenient and efficient 3D object manipulation.

Why Gaze-Supported?

- Gaze indicates intention.
- Gaze is fast.
- Gaze is lightweight.
- However, gaze does not afford 3D interaction.
- Gaze is inaccurate

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What is Object Manipulation?

Manipulate Phase: the translation, rotation, and scaling of objects.

Design Dimensions of The Manipulate Phase

Which input mechanism of gaze and hand has been integrated into the manipulate phase (translation, rotation, scaling).

HAND AND GAZE VS. HAND ONLY

Integration

When starting the manipulate phase, if the indicated target will snap to the hand position or remain in its original place.

REMOTE MAPPING VS. DIRECT MAPPING

Coordination

If both input mechanisms are involved, whether the transition between gaze and hand input is explicit or implicit.

IMPLICIT TRANSITION VS. EXPLICIT TRANSITION

Transition

Literature Review

By classifying the existing techniques with our design space, we identified the following gaps:

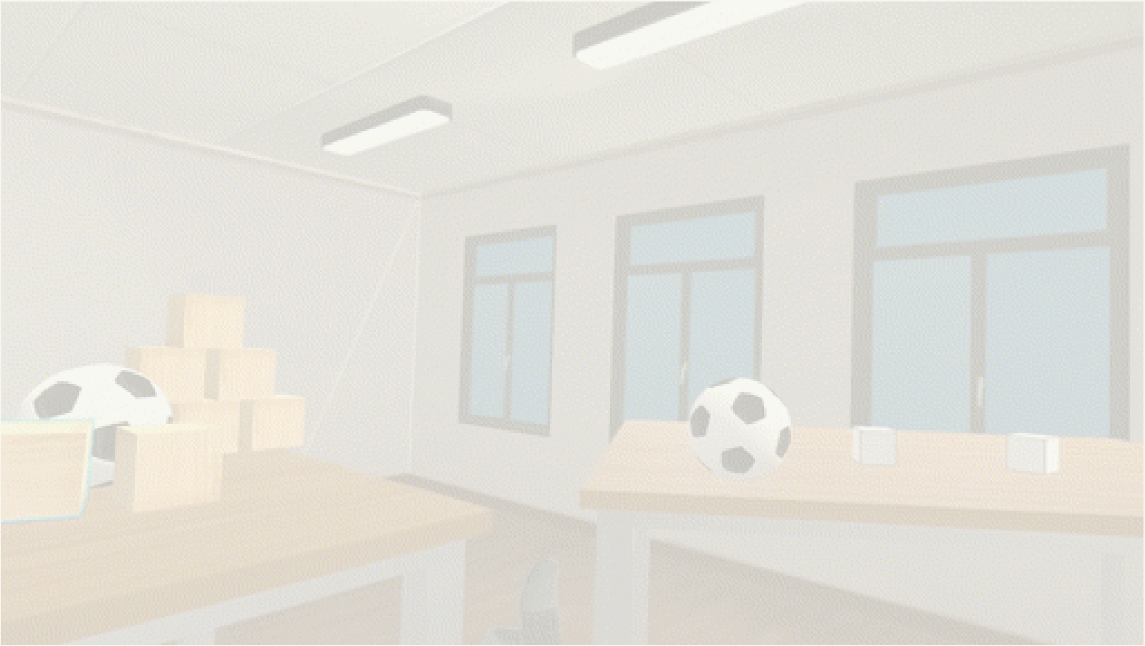
- Implicit transition is still under-explored for target manipulation tasks in general.
- Transition mechanisms between gaze and hand input have not been investigated in the manipulate phase in 3D.
- Techniques that leverage different elements of the design space have not been compared in terms of their efficiency and usability.

	Techniques	**Integration**		**Coordination**		**Transition**		
		Gaze	Hand	Direct	Remote	Implicit	Explicit	None
	Eye drop [61, 62]		✓	✓				✓
	TouchGP [55]	✓	✓		✓		✓	
	Gaze-Touch [39]		✓		✓			✓
2D	TouchT [59]		✓		✓			✓
	GazeT [59]	✓	✓		✓		✓	
	MagicT [59]	✓	✓		✓		✓	
	Gaze [66]		✓		✓			✓
	Gaze + Non-touch [42]		✓		✓			✓
	Three-point [52]	✓	✓	✓				✓
	Gaze + pinch [40]		✓		✓			✓
	GG interaction [45]		✓		✓			✓
3D	Gaze + Gesture [9, 10, 54]		✓		✓			✓
	Gaze Grab		✓	✓				✓
	Remote Hand		✓		✓			✓
	3D Magic Gaze	✓	✓		✓		✓	
	Implicit Gaze	✓	✓		✓	✓		

Technique Demonstration

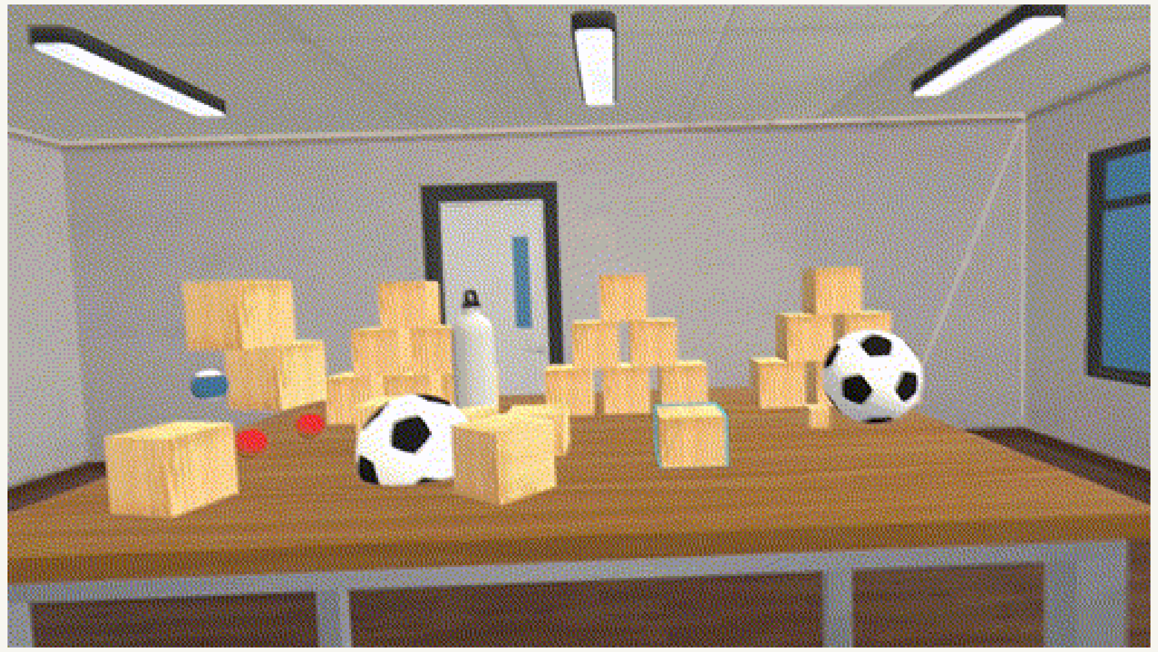
GazeGrab

RemoteHand



3DMagicGaze

ImplicitGaze

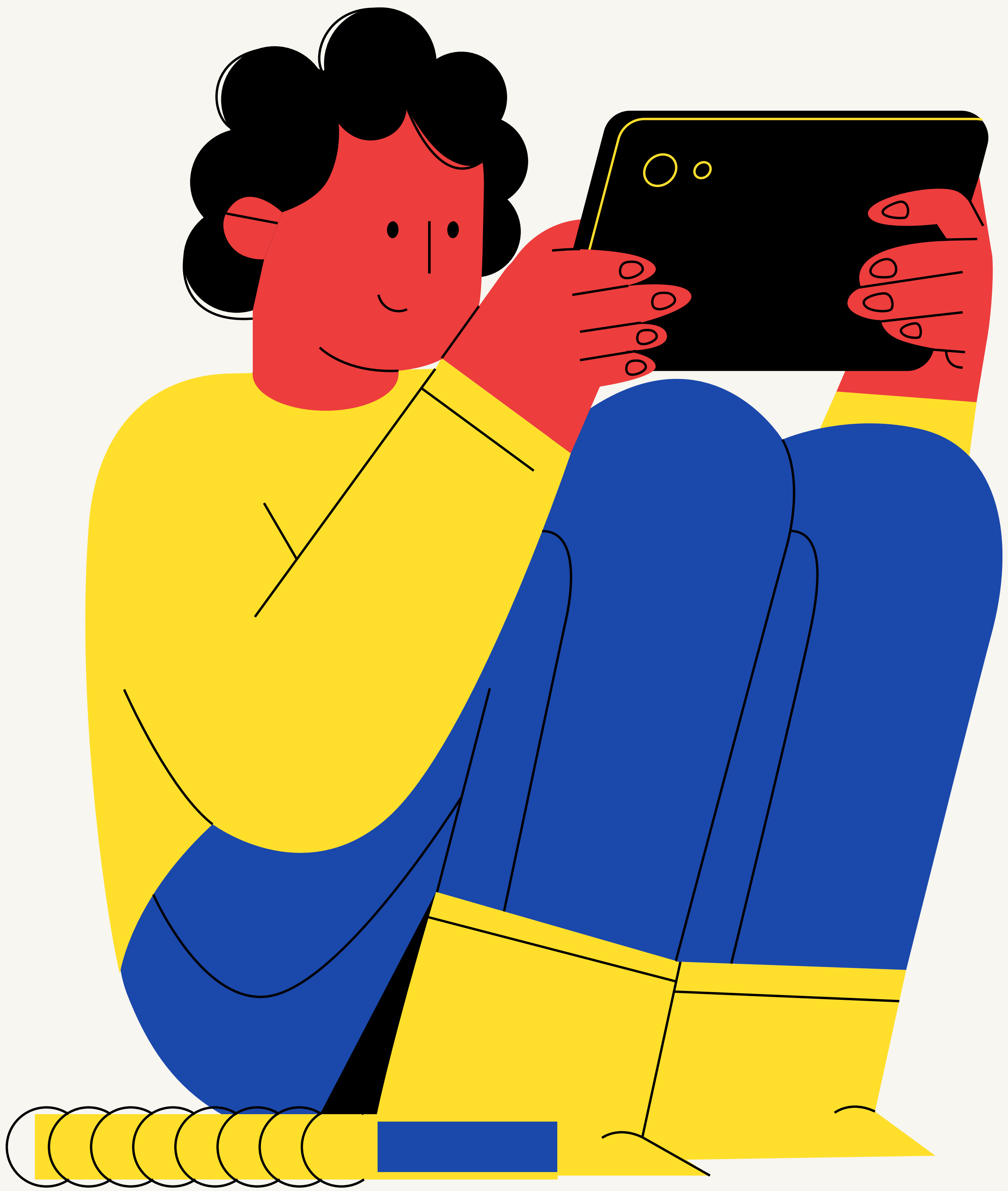


Study 1

Technique evaluation and comparison in a controlled working space (in front of the user and within arm-reach distance)

Study 2

Assess how techniques perform in a larger environment and when applied to realistic workflows (reconstruct an empty room following a miniature + DIY).



Study 1

Controlled Evaluation

Study Overview

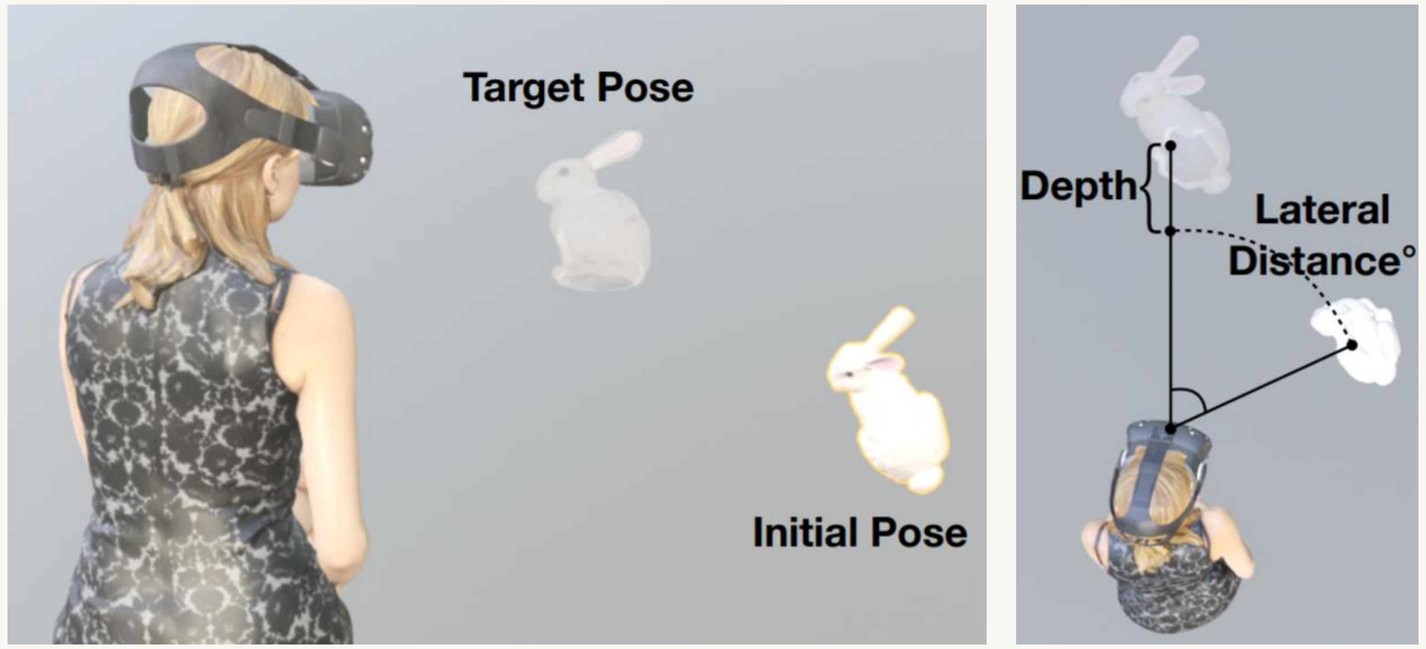
Study Goal

Evaluate and compare the four gaze-supported manipulation techniques that leveraged different design features from the presented design space in a controlled working space.

Independent Variables

- Technique (GazeGrab, RemoteHand, 3DMagicGaze, and ImplicitGaze)
- Lateral Distance (35° and 55°)
- Depth (0.05m, 0.10m, and 0.15m)

Task



Dependent Variables

- Performance Measures: Manipulation Time, Coarse Translation Time, Re-position Time
- Hand Fatigue Approximations: Hand Movement Distance, Hand Rotation Angles
- Subjective Measures: Borg CR 10, Single Easement Questionnaire, NASA TLX, Subjective Ranking

Overall, 1440 trials of data (= 4 Techniques × 3 Lateral Distance × 3 Depth × 5 Repetitions (Rotations) × 12 Participants)

Study 1 Findings

Finding 1: Integration

Our results show no evidence that manipulating objects based on both eye and hand input can offer significant performance benefits in VR manipulation tasks over the hand-only approach in the primary working space.

Finding 2: Coordination

Direct hand mapping can lead to more arm fatigue than remote hand mappings. However, it might help users to determine how to optimally rotate an object to the target configuration.

Finding 3: Transition

Implicit transition and explicit transition led to similar task performance, while implicit transition required less effort (e.g., hand movement) than explicit transition.

Study 2

Application

Study Overview

Study Goal
Assess how gaze-supported manipulation techniques perform under a larger environment and when applied to realistic workflows.

Interaction Scenario
Participants were instructed to reconstruct an empty room following a miniature using the manipulation techniques. Different from Study 1, we emphasized the “design-by-yourself” concept, where the techniques were integrated into users‘ own workflow and creative experiences.

Measures
- Participants’ oral feedback
- User Experience Questionnaire (UEQ)

Study 2 Findings & Implications

Finding 1: Integration

Gaze input can speed up the transformation in the lateral space for distant objects.

→ Hand amplification in the depth dimension.

Finding 2: Coordination

Snapping the target to the hand position is efficient for bringing distant objects to the user. However, repetitive snapping close objects to hands can cause make the fine-grained adjustment difficult.

→ Disable the snapping function when object is close.

Finding 3: Transition

Providing an implicit transition between gaze and hand input can enable the smooth and concurrent transformation. While attaching (large) objects in the gaze pointing direction can cause visual clutter.

→ Making the attached object transparent.

Conclusion

This paper investigates integration, coordination, and transition strategies of gaze and hand input for 3D object manipulation in VR.

Our study results show that show gaze input does not offer significant performance benefits for object manipulation in the primary working space but can be useful for larger spaces with distant objects. Gaze input was also shown to mitigate the arm fatigue issue.

We do not advocate a one-size-fits-all technique, while different gaze-support mechanisms can provide benefits for building more usable and efficient VR applications.

Future work can investigate new methods for implicit transition.

Thanks for your Attention!

Presenter

Difeng Yu

Title

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location

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