Virtual Equipment System

Designing Hyperphysical User Interface and Whole-Body Interaction in Extended Reality

Powen Yao



LinkedIn/Facebook/Google/Wechat: powenyao

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Virtual Equipment System

Designing Hyperphysical User Interface and Whole-Body Interaction in Extended Reality Face Mask and Voodoo Doll for User Privacy and Self-Expression Options in Virtual Reality

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Background

Virtual Equipment System

Privacy Equipment Set

Privacy Mask

Voodoo Doll

Camera

Demo Video

Future Expansions

Additional Topics

Background

Extended Reality (XR)



Figure: Reality-Virtuality (RV) Continuum diagram

P. Milgram, H. Takemura, A. Utsumi, and F. Kishino, "Augmented reality: A class of displays on the reality-virtuality continuum," 1995, vol. 2351, pp. 282–292.

Qualities of XR

• User as part of the computing environment

• Interaction in 3D

• Immersive Technologies tracking more of the user's traits



XR and Its Many Contexts

- 1. User Postures:
 - a. Sitting, Standing, Roomscale, Arena-Scaled, Lying Down

2. Mobile Augmented Reality:

- a. Walking, Riding Vehicles, Driving Vehicles
- 3. Unusual Environments:
 - a. Zero-Gravity Space, Underwater
- 4. Different Contents:
 - a. Entertainment, Health, Training, Work, Social
- 5. Many Existing 3DUI Techniques:
 - a. 100+ locomotion techniques, seven high impact taxonomies for locomotion techniques

Welcome to Room Setup!

Set up for Room-Scale

Play Room-Scale, Standing, and Seated VR experiences. Choose this if you have at least 2 meters by 1.5 meters, or around 6.5 by 5 feet.

Set up for Standing Only

Play Standing and Seated VR experiences. Choose this if you have limited space to walk around.





ROOM-SCALE

STANDING ONLY

User Postures: Sitting, Standing, Room scale, ArenaScale, Lying Down





Unusual Environments: Zero-Gravity Space, Underwater



Different Contents: Work, Sport, Training, Medical Entertainment, Health, Social

Locomotion Vault

Massimiliano Di Luca, Hasti Setti, Siman Egan, Mar Gonzalez-Franco, "Locamotion Vault: the Extra Mile in Analyzing VR Locomotion Techniques." In Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems, pp. 1–10. 2021. (DOI: 10.1145/3411764.3445319, pdf)



Many Existing 3DUI Techniques: 100+ locomotion techniques, seven high impact taxonomies for locomotion techniques

XR UI Challenges

- 1. Many different contexts, scenario, situations with the user as a part of the computing environment
- 2. Many techniques to address the different contexts and scenario, each with different strengths and weaknesses
- Lack of a unified system control interface to allow the user to utilize the best technique for the situation at hand
- 4. Need for a way to evaluate techniques for different contexts

Approach

- Identify two critical qualities of XR: Hyperphysicality and Whole-Body Interaction
- 2. Utilize Hyperphysicality and Whole-Body Interaction as Lens for Design
- 3. **Prototype** different Interaction Techniques
- 4. **Evaluation** with focus on Hyperphysicality and Whole Body Interaction

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Yao, Powen, Tian Zhu, and Michael Zyda. "Designing Virtual Equipment Systems for VR." *International Conference on Human-Computer Interaction.* Springer, Cham, 2020.

Data-in (Sensory Setting)

Sensory Set provides user an (universal) way to quickly adjust sensory settings through a body-centered 3D User Interface.

MICROPHONE

BELT

POCKET

- Virtual Headphones
- Virtual Goggles

- Virtual Microphone
- Virtual Controller
- Virtual Shoe

- Audio Settings
- Visual Settings

- Audio Recording Settings
- Haptics/Interaction Settings
- Locomotion Settings

Yao, Powen, Vangelis Lympouridis, Tian Zhu, and Michael Zyda. "Interfacing with Sensory Options Using a Virtual Equipment System." In Symposium on Spatial User Interaction, pp. 1-2. 2020.

HEADPHONES

BRACERS

GOGGLES



Mirror reflection of the user performing a up Equipment Gesture with the Virtual Headphone to increase the audio volume

Volume: 80%







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Privacy Equipment Set

Need for Privacy Management

- Trend of XR Headsets that capture more user data than before
- Heart rate monitoring, pupillometry, eye-tracking, facial expression, and so on
- Fingerprints can be collected from photographs; reflections in pupils can reveal subject's location
- User can be identified with passive data gathered from users such as motion controller data



Powen Yao, Vangelis Lympouridis, Michael Zyda. **"Virtual Equipment System: Face Mask and Voodoo Doll for User Privacy and Self-Expression Options in Virtual Reality**" 2021 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops

VES for Privacy

• We applied VES to a new and different context - **privacy**

- Sensory Setting Incoming data to the user
- Privacy Setting Outgoing Data
 - Also related to self
 expression and
 cosmetics
- Avatar/Presence Setting -Location for incoming and outgoing data

VES for Privacy

- VES Addition for Privacy
 - Privacy Equipment for Body Parts
 - Privacy Mask
 - Voodoo Doll
 - Cameras



Privacy Equipment for Body Parts

VES Addition for Privacy

- Privacy
 Equipment
- Privacy Mask
- Voodoo Doll
- Cameras

- We introduce privacy equipment for different body parts
 - Privacy Eye Equipment
 - Privacy Mouth Equipment
 - Privacy Hand Equipment,
 - Etc

Multiple Equipment Sets

Equipment Set

- Sensory Set
- Privacy Set
- Avatar Set

They utilize many of the same locations!

Eye Location

- Sensory Set Adjust Brightness
- Privacy Set Turn on/off eye tracking
- Avatar Set Create Eye Avatars to see distant locations



Challenges

VES Addition for Privacy

- Privacy Equipment
- Privacy Mask
- Voodoo Doll
- Cameras

• Challenges in using VES

- VE for privacy may fight for the same physical space as VE for sensory settings as well as other VE
- Equipment near body parts cannot fully represent the privacy options that a user need
- Different privacy setting needed to address different audience

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Privacy Mask

VES Addition for Privacy

- Privacy Equipment
- Privacy Mask
- $\circ \quad \text{Voodoo Doll} \\$
- Cameras



- Putting on Face Mask to enter Incognito Mode
- Interaction with Face Mask changes the current Equipment Set to Privacy Equipment Set



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- Putting on Face Mask to enter Incognito Mode
 - Interaction with Face Mask changes the current Equipment Set to Privacy Equipment Set

Privacy Mask

VES Addition for Privacy

- Privacy Equipment
- Privacy Mask
- Voodoo Doll
- Cameras



While hovering over
the privacy mask, the
active equipment set
will also switch to the
privacy equipment,
allowing you to utilize

Privacy Mask

VES Addition for Privacy

- Privacy Equipment
- Privacy Mask
- Voodoo Doll
- Cameras

Alt Node Interaction
 with Privacy Mask will
 bring detailed privacy
 menu



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Voodoo Doll

Privacy Equipment Set

- Proposed Solution:
 - Voodoo Doll Technique is utilized for user to fine tune privacy options
 - The Voodoo Doll is a symbolic representation of the user in terms of privacy settings.





Figure 1: Manipulating a pin and toy soldier with dolls held in the dominant and non-dominant hands. In all figures we added the user's hands to the image for increased clarity.
VES combined with Voodoo Doll Technique





- Voodoo doll
- Cameras
- Background Panel
- Floor Panel

 The user can interact with any of the 3 to enable/disable privacy tracking or to tweak the privacy options.



Voodoo doll represents the user and privacy options



 Cameras represent different subscribers to the user's privacy data



Background Panel represents background data such as the user's background imagery or background noise



• Voodoo doll

- Ease of access
- Visualization

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Default Interaction

- The user is disabling pulse tracking by interacting with the voodoo doll's heart
- The user grabs the heart from the voodoo doll using the left controller
- The user can pull the trigger on the controller to disable tracking of heart-related information. In this case, it's to disable pulse rate



Alt Node Interaction

- These body part from the doll can also be placed into the alt node to bring up detailed menu related to that body part.
- Eye
 - Eye tracking
 - Color
 - Pupil shape
 - Size



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Additional Topics





Privacy Equipment for Body Parts

- Interaction System
 - Avatar Facial Expressions
 - Open mouth to breath fire
 - "Weeping Angel" from Doctor Who

- Data Collection
 - Telemetry
 - Data Logs

Primary Camera
Overrides all cameras

- Multiplayer
 - Facial Expression
 - Hand Gesture
 - Position



- Red are body parts with tracking disabled
- Gray are body parts that are
- not tracked
- Green camera represents the perspective in which we are seeing the user's privacy data status

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https://youtu.be/RazSyF9W1nU

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Additional Topics

Future Expansions

Subcamera For Each Camera Category

- Interaction System
 - Based on different applications
 - 0
- Multiplayer
 - based on user types
 - Strangers
 - Friends
 - Blocked Users

- Data Collection
 - Based on different services
 - Meta
 - Apple
 - Netflix
 - Google
 - Amazon

Voodoo Doll Templates

- Additional Voodoo Dolls can represent a preset
 - Trusted
 - Default
 - Minimal
 - Healthcare



Camera Filters

- With Camera as metaphors, we can also add other related metaphors
- Filters could be another way to apply a series of modification to what the camera will see
- A filter could also simply be not show anything or show a completely unrelated representation

Samples

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Other Privacy Options

 Any options that are not associated with the voodoo doll, the background, or the camera, are listed on a side menu

- Example
 - O User's GPS location
 - O Tracking cookies



Background

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Additional Topics

Additional Topics

- Equipment Sets can function and influence the user at the same time, despite the user being able to interact with one at a time
- If you are wearing a helmet, but you can't touch it right at this moment, what is it?
- Similar to the popculture idea of objects in different dimensions
- Equipment Sets belonging to different dimensions (permissions) can help us organize Equipment Sets for different contexts, which alleviate the issues of the many contexts in XR



• Certain interactions should be in another "dimension" or permission

• For example, inputting your password



Chen, Sibo, et al. "Exploring word-gesture text entry techniques in virtual reality." *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems*. 2019.

https://dl.acm.org/doi/fullHtml/10.1145/3290607.3312762

- Certain interactions should be in another "dimension" or permission
 - For example, inputting sensitive information such as user name and password

 Multiple users could be in the same physical space without intruding on each other's personal space by putting them in a different dimension

• Dimensional Shift





Dimensions = Permissions = Ghosts?

Term	Regular Objects	Held Objects	Ethereal	General	Personal	Data	Invisible	Pollution
			Intangible	Cosmetics	Cosmetics	Logging?	Objects	Haunted
								Scripted
Example	Radio in the	Radio Grabbed	Ghosts				Invisible	
	World	by User					Radio	
Cosmetics (Everyone)	Y	Y	Y	Y	Y	N	N	N
Cosmetics (User)	Υ	Y	Y	Υ	Υ	N	N	N
Interactions (Everyone)	Y	N	N	Y	N	Y	Y	N
Interaction (User)	Y	Y	N	Υ	Υ	Y	Y	Ν
Effects (Everyone)	Υ	Y	Y	N	N	N	Y	Y
Effects (User)	Y	Y	Y	N	N	N	Y	Y

Doll? Avatar? Puppeteering

- If there's a voodoo doll that represent your privacy, there can also be a voodoo doll that you puppeteer that represent you
- You can make the avatar do things that you may not be able to do.
- Your avatar could be waving hands high in the air while you are just sitting
- Emoticon applied to the whole avatar's body
- Similar to Vtubers

Actual	Remapped Hand Height
\bigcirc	
	Maximum Arm reachable height

Summary

- Virtual Equipment System provides the user with equipment slots and equipment that serve as interface or can be used for further interactions
- Privacy Equipment Set can be used to quickly adjust privacy related to body parts
- Privacy Mask, Voodoo Doll, and Camera can be powerful visualization metaphors and tool for managing user privacy
- Hyperphysicality As Design Lens can lead to Dimensionality which can be useful in providing new ways of thinking about privacy

Thank you

Virtual Equipment System

Face Mask and Voodoo Doll for User Privacy and Self-Expression Options in Virtual Reality

Powen Yao



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Any sufficiently advanced technology is indistinguishable from magic.

Arthur C. Clarke

Hyperphysicality in Literature

Work that utilize hyperphysicality

- J. S. Pierce, B. C. Stearns, and R. Pausch, "Voodoo dolls: seamless interaction at multiple scales in virtual environments," in Proceedings of the 1999 symposium on Interactive 3D graphics - SI3D '99, Atlanta, Georgia, United States, 1999, pp. 141–145. doi: 10.1145/300523.300540.
- R. Stoakley, M. J. Conway, and R. Pausch, "Virtual reality on a WIM: interactive worlds in miniature," in Proceedings of the SIGCHI conference on Human factors in computing systems - CHI '95, Denver, Colorado, United States, 1995, pp. 265–272. doi: 10.1145/223904.223938.
- I. Poupyrev, M. Billinghurst, S. Weghorst, and T. Ichikawa, "The Go-Go Interaction Technique: Non-linear Mapping for Direct Manipulation in VR," p. 2.
- P. Lubos, G. Bruder, and F. Steinicke, "Are 4 hands better than 2?: bimanual interaction for quadmanual user interfaces," in *Proceedings of the 2nd ACM*



Fig. 4: The Go-Go technique allows users to expand their reach. The white cube shows the real hand position.



Figure 1: Manipulating a pin and toy soldier with dolls held in the dominant and non-dominant hands. In all figures we added the user's hands to the image for increased clarity.



Figure 1: The World In Miniature (WIM) viewed against the background of a life-size virtual environment.

Equipment Sets

Multiple Equipment Sets

- Different set can be seen as belonging to a different dimension
- Alternatively, having different permission setting
- We just need easy to use tools to access that different dimension or permission



Figure 1: For the latest configuration of the standard VES context, the user is equipped with the Avatar Tool in the Avatar-Slot and Privacy Mask Tool in the Mask-Slot.

Powen Yao, Vangelis Lympouridis, Michael Zyda. "Virtual Equipment System: Expansion to Address Alternate Contexts." International Conference on Human-Computer Interaction. Springer, Cham, 2021.

Equipment to Switch and Access Equipment Sets

Set Switch Tool

Universal Set Switch Tool



Figure 5: Left to Right: 1) User is equipped with Virtual Goggles and the Avatar Tool which functions as a Set Switch Tool 2) The User moves and hovers one controller over the Avatar Tool to trigger the set switch. The Equipment Set is now switched to the Avatar Set with Arcane Eyes. 3) The user grabs Arcane Eyes from Avatar Set
Multiple Equipment Sets

- 1. **Sensory Set:** To interact and alter incoming sensory data (i.e.audio-visual data)
- 2. **Privacy Set:** To interact with outgoing data in terms of privacy
- 3. **Management Set:** To interact with and manage the different VES that are currently active
- 4. **Cosmetic Set:** To interact with outgoing data in terms of self-expression
- 5. **Avatar Set:** To control the presence of the user's avatar
- 6. **Dev Set:** To access developer or debug options
- 7. **Personal Set:** VES as set up and customized by the user
- 8. **App/Game-Specific Set:** Sets that are used for a specific application or game experience

Background

Hyperphysicality

Whole-Body Interaction

Body of Work

Virtual Equipment System

Virtual Equipment System

Machine Learning in VES

Contributions

What is a VES?

• Virtual Equipment System (VES) is a body-centric 3D user interface system that takes advantage of the user's sense of the body in immersive environments.

- Virtual Equipment can be designed for different contexts and offered to the users as different **Equipment Sets**.
 - Sensory Equipment Set
 - Privacy Equipment Set
 - Avatar Equipment Set
 - etc



Key Points

Representation

- Egocentric Equipment expanded to include Peripersonal and Extrapersonal Space
- Egocentric Equipment can include traditional Exocentric Equipment and workspace
- Equipment in alternate space (list-space, tab-space, etc)

• Interaction

- Multiple Egocentric Equipment can reside in the same Equipment Slot (same location)
- Egocentric Equipment in the same physical space, but in different dimensions
- Accessing equipment not stored in physical space via multi-modal interaction
- Equipment Gestures
 - Surface Gestures
 - Motion Gestures
- Hybrid Interaction with other techniques
- Multi-Modal Interaction

- Effect
 - Equipment in other dimensions can have effect
 - Sensory Setting
 - Privacy Options
 - Avatar Presence
 - Self-Referential Modification

Key Qualities of VES

- Egocentric vs Exocentric
- Personal, Peripersonal, and Extrapersonal Space
- Dimensions, Permissions, Alternate Realities
- Equipment Effects: Active Participation, Passive Participation, Directional, Constant

•

What is an equipment?

- Equipment
 - "The things that are needed for a particular purpose or activity"
 - Oxford Learner's Dictionaries

- Personal Protective Equipment (PPE)
 - "Clothing and equipment that is worn or used to protect people against infection or injury."
 - Oxford Learner's Dictionaries
 - "Personal" and "Worn"



Egocentric vs Exocentric

Egocentric equipment: Objects that follow the user in the virtual space.

Exocentric equipment: Objects that stays fixed to their location in the world.

R. Khadka and A. Banic, "Effects of Egocentric Versus Exocentric Virtual Object Storage Technique on Cognition in Virtual Environments," in 2020 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW), Atlanta, GA, USA, Mar. 2020, pp. 205–209. doi: 10.1109/VRW50115.2020.00044.

Egocentric vs Exocentric

The virtuality of the equipment means real physical laws that limited a real-life equipment from being an egocentric equipment do not need to apply.

E.G. Bookshelves or Garage Workbench



Personal, Peripersonal, Extrapersonal Space

Proxemics: The study of human use of space

- Intimate Distance
- Personal Distance
- Social Distance
- Public Distance

- Personal Space (PS)
 - Pericutaneous space
- Peripersonal Space (PPS)
 - Reaching Space
 - Near Space
- Extrapersonal Space (EPS)
 - Far Space

E. T. Hall, "A System for the Notation of Proxemic Behavior," *Am. Anthropol.*, vol. 65, no. 5, pp. 1003–1026, Oct. 1963, doi: 10.1525/aa.1963.65.5.02a00020. G. Rizzolatti, C. Scandolara, M. Matelli, and M. Gentilucci, "Afferent properties of periarcuate neurons in macaque monkeys. II. Visual responses," *Behav. Brain Res.*, vol. 2, no. 2, pp. 147–163, Mar. 1981, doi: 10.1016/0166-4328(81)90053-X.

Personal, Peripersonal, Extrapersonal Space

Personal space: the area immediately bordering the body.

Peripersonal space: the area that is within the distance of the user's hand reach.

Extrapersonal space: the area beyond the user's hand reach.



Image from "Peripersonal Space in Virtual Reality: Navigating 3D Space with Different Perspectives" by Jooyeon Lee, M. Cheon et al

Personal, Peripersonal, Extrapersonal Space

Personal Equipment: Egocentric Equipment that exists in the user's personal space. In other words, equipment that is immediately next to the user's body.

Peripersonal Equipment: Egocentric

Equipment that exists in the user's peripersonal space. In other words, equipment that is within the user's hand reach.

Extrapersonal Equipment: Egocentric

Equipment that exists in the user's extrapersonal space. In other words, equipment that is within the user's tool reach.



Image from "Peripersonal Space in Virtual Reality: Navigating 3D Space with Different Perspectives" by Jooyeon Lee, M. Cheon et al





Extending VES to Peripersonal Space

- Constrained by laws of physics, personal equipment in real life are constrained in the personal space.
- In Virtual Reality, personal equipment do not need to be restricted to close proximity with a body part.
 - Most pockets, belts, and holsters in VR experiences are in proximity to the waist to emulate real life



Image from "Peripersonal Space in Virtual Reality: Navigating 3D Space with Different Perspectives" by Jooyeon Lee, M. Cheon et al

Extending VES to Peripersonal Space

The Invited Review Work[8] by di Pellegrino et al. showed that **Peripersonal Space can be centered around various body parts**, such as centered around the hand, head, or the torso (body trunk). Peripersonal Equipment based On:

- Left Arm
- Right Arm
- Head
- Torso

G. di Pellegrino and E. Làdavas, "Peripersonal space in the brain," *Neuropsychologia*, vol. 66, pp. 126–133, Jan. 2015, doi: 10.1016/j.neuropsychologia.2014.11.01 1. Upcoming work involves expanding VES to peripersonal space, meaning that we can grab objects out of thin air in virtual reality, an ability commonly found in fantasy settings

(Work in Progress) Virtual Equipment System: Equipment in Peripersonal Space; Bringing Hammerspace to Virtual Reality User grabbing swords from the spherical sockets around the user's body. User must use slice the cubes using a sword of matching color

Equipment Effects

• Active Participation vs Passive Participation

• Standard vs Cosmetics

• Directional vs Omnidirectional/Constant

Active Participation vs Passive Participation

Active Participation

The user must make a conscious action involving the equipment for the effect to occur.

Passive Participation

Once equipped and/or activated, it requires no conscious action involving the equipment for the effect to occur.

In real life, this would typically refer to clothing or protection gear.

Active Participation	Passive Participation
Active Sonar	Passive Sonar
Shield in user's hand	"Animated Shield"
Torch or Flashlight in user's hand	Floating Lantern
	Armor for a stat bonus

Cosmetic vs Standard Item

Term	Regular Objects	Held Objects	Ethereal Intangible	General Cosmetics	Personal Cosmetics	Data Logging?	Invisible Objects	Pollution Haunted Jackass Scripted
Example	Radio in the	Radio Grabbed	Ghosts				Invisible	
	World	by User					Radio	
Cosmetics (Everyone)	Y	Y	Y	Y	Υ	N	N	N
Cosmetics (User)	Y	Y	Y	Y	Y	N	N	N
Interactions (Everyone)	Y	N	N	Y	N	Y	Y	N
Interaction (User)	Y	Y	N	Y	Y	Y	Y	N
Effects (Everyone)	Y	Y	Y	N	N	N	Y	Y
Effects (User)	Y	Y	Y	N	N	N	Y	Y

Types of Equipment based on VES Qualities

User-centric in terms of movement	Location related to human body	Functionality	Participation Needed for Effect	
Egocentric	Personal	Standard	Active-Participation	Equipment
Exocentric	Peripersonal	Cosmetics	Passive-Participati on	
	Extrapersonal			

Publications

Publications

List of Publications

Powen Yao, Tian Zhu, and Michael Zyda. "Adjustable Pointer in Virtual Reality for Ergonomic Interaction." 2020 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW). IEEE, 2020.

Powen Yao, Tian Zhu, and Michael Zyda. "Designing Virtual Equipment Systems for VR." *International Conference on Human-Computer Interaction*. Springer, Cham, 2020.

Powen Yao, Vangelis Lympouridis, Tian Zhu, Michael Zyda. "Interfacing with Sensory Options Using a Virtual Equipment System." *Symposium on Spatial User Interaction*. 2020.

Powen Yao, Vangelis Lympouridis, Tian Zhu, Michael Zyda, Ruoxi Jia. "Punch Typing: Alternative Method for Text Entry in Virtual Reality." *Symposium on Spatial User Interaction*. 2020.

Powen Yao, Vangelis Lympouridis, Michael Zyda. "Virtual Equipment System: Face Mask and Voodoo Doll for User Privacy and Self-Expression Options in Virtual Reality" 2021 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops



Powen Yao, Vangelis Lympouridis, Michael Zyda. "Virtual Equipment System: Expansion to Address Alternate Contexts." *International Conference on Human-Computer Interaction.* Springer, Cham, 2021.

Zezhen Xu, Powen Yao, Vangelis Lympouridis. "Virtual Control Interface: A System for Exploring AR and IoT Multimodal Interactions Within a Simulated Virtual Environment"

Recent Submissions

Toward Predicting User Waist Location From VR Headset and Controllers Through Machine Learning A Jothi, P Yao, A Zhao, M Miller, S Swieso, M Zyda Symposium on Spatial User Interaction, 1-2

Toward Using Machine Learning-Based Motion Gesture for 3D Text Input S Swieso, P Yao, M Miller, A Jothi, A Zhao, M Zyda Symposium on Spatial User Interaction, 1-2

Virtual Equipment System: Toward Peripersonal Equipment Slots with Machine Learning M Miller, P Yao, A Jothi, A Zhao, S Swieso, M Zyda Symposium on Spatial User Interaction, 1-2

Publications

Work-in-Progress

Toward Using Multi-Modal Machine Learning for User Behavior Prediction in Simulated Smart Home for Extended Reality

Toward Bag of Holding and other Extradimensional Storages in Extended Reality

Using Hyperphysicality as Lens for Design for Virtual Equipment in Virtual Reality

Flick Typing: A New XR Text Input System Based on 3D Gestures and Machine Learning

Towards Sensor Fusion Based Pose Estimation for Virtual Reality

Powen Yao, Vangelis Lympouridis, Michael Zyda. "Virtual Equipment System: Alternate Avatars, Arcane Eyes, and Magic Ears for Hyper-physical Interactions in Virtual Reality."

XROS UI Project

Project Codebase:

https://github.com/powenyao/XR-Interaction-Toolkit-Examples

Project Website:

https://powenyao.github.io/XR-Interaction-Toolkit-Examples/website/index.html

Relevant Youtube Videos

https://www.youtube.com/playlist?list=PLQkQPxKAn5cRffVUPzxOg6kWXBP46UCV_