Co-presence in MR Museum

On the magnitude of physical and behavioral manifestation

Taewook
Eunseo

Contents

Introduction

- Background
- Novelty of Subject

Background: Urge for MR Museum

Physical Museums	Virtual Museums	Mixed Reality Museums
losing its aura	not fully immersed/accepted, following the general order of internet -commercialization and quick transfer of interests	bringing tele-presence to physical space and bringing out phsycal aura of museums to virtual spaces.

-> **a living space** where information, objects and human converge together
focused on **‘‘co-presence’ with physical and behavior cues built on the MR system.**

Research Objective: Co-presence in MR museum

Direct communication /Face to Face interaction

Spatial Co-presence Facing one direction

Mixed Reality Museum environment that involves users in physical and virtual and conducted a comparison experiment on physical and behavior cues: Visual cue (emotional gesture and shadow) and audio cue(spatial audio)

-> **Examine and compare the ways to enhance co- presence without direct communication in MR Museum Environment**

Literature Review

- Co-presence and Social Presence
- Modalities and Predictors in Related works

Co-presence and Social Presence

- How is a ‘sense of being there’ formed in a mediated environment?

Classification of Concepts	Definition of Social/Co-presence
Salience of the other	"The degree of salience of others in interactions and the consequent salience of interpersonal relationships. Subjective characteristics of the communication medium." (Short et al)
Perceived access to another intelligence	“The degree of social presence refers to the degree to which a user can perceive the intelligence, intentions, and sensory impressions of others.” (Biocca)
Mutual Understanding	"Social presence is the ability to make yourself known in a situation where media abundance is low."(Savichi and Kelly)
Co-location	"The feeling of being in the same room with the people you are collaborating with" (Heeter et al.)
Interactivity of the other	"the extent to which other beings appear to exist and respond to the media user" (Durlach and Slater)
Sense of being together	"The degree to which you feel together in a virtual space" (Sallnas et al.)
Perceived Co-presence	“The degree to which one feels socially present” (Nowak) “The degree to which the other party is involved in the interaction” (Gofman) “The ability to experience other people with their senses as they are.” (Biocca and Nowak)

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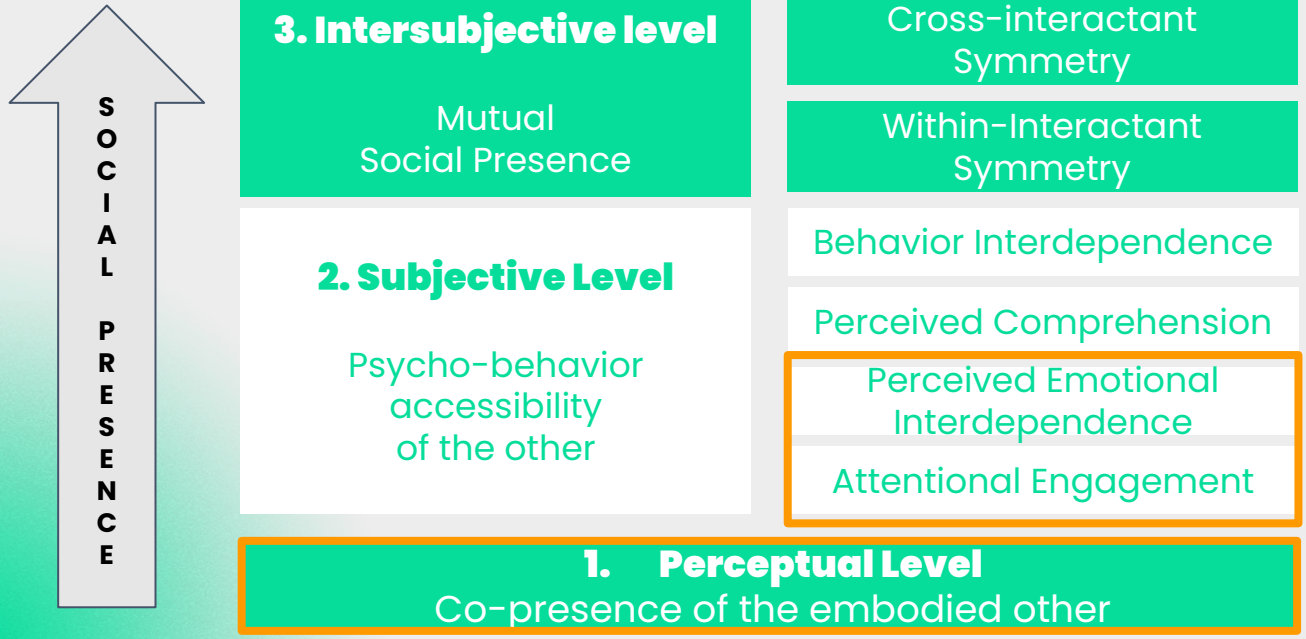
Levels and Dimensions of Social Presence

- NetMinds social Presence Inventory



Modalities and Predictors in related works

Predictor	저자	Details	Platform
Visual representation	Daniel Roth et al.	Behavior realism (Mutual gaze) Social cue	VR
Visual representation	Bente et al.	Behavioral realism (Mutual gaze)	Screen
Visual representation	Bente et al.	Photographic realism (Low vs. High fidelity avatar)	Screen
Visual representation	Boram Yoon et al.	Avatar appearances (head & hands vs. upper body vs. whole body)	MR
Visual representation	Thammathip Piumsomboon et al.	avatar's head and hands vs. Field of View (FoV) frustum cue vs. gaze cue	MR
Visual representation	Scott W. Greenwald et al.	face-to-face vs. avatar	VR
Visual representation	Tahir Mahmood et al.	Visual cue vs. avatar	AR
Visual representation	Kim et al.	hand only vs. hand + sketch vs. hand + pointer vs. hand + sketch + pointer	MR
Visual representation	Mitchell Norman et al.	Remote Visual cue vs. Ojbect manipulation	MR
Visual representation	Arjan Egges et al.	Posture, Gesture and Diffuse Shadow merged (DSM)	AR, MR
Visual representation	Jacqueline M. Fulvio et al.	action-contingent 3d visual cue vs. sensory cues	VR
Visual representation	Abdeldjallil Naceri et al.	size-distance in depth perception	VR
Visual representation	Jacqueline M. Fulvio et al.	monocular and binocular cues of motion of objects through depth	VR
Visual representation	Daniel Paes et al.	Pictorial Realism	VR
Social cues	C. Wienrich et al.	Social interdependence vs. non-Social interdependence	VR
Social cues	Tibert Verhagen et al.	Smiling	Web
Social cues	Katrin Allmendinger et al.	avatar with nonverbal signals vs. without nonverbal signals	Screen

Predictor	저자	Details	Platform
Social cues	Justin Andrew Liao et al.	Public speaking - virtual audience with natural non-verbal behavior	VR
Social cues	Daniel Roth et al.	physical-based vs. verbal-based social interactions	VR
Social cues	Mark Roman Miller et al.	nonverbal behavior	AR
Social cues	Daher et al.	Exposure to other person interacting with VH	VR
Social cues	Fortin and Dholakia	Low vs. Medium vs. High interactivity	VR
Social cues	Lee and Shin, 2012	Low vs. High interactivity	Web
Audio cues	Kim	Number of different voices (single vs. multiple)	AR
Audio cues	Hansung Kim et al.	Immersion	AR, VR
Audio cues	Lukas Aspöck et al.	Immersion	VR
Audio cues	Miroslaw Narbutt et al.	Immersion	VR
Audio cues	Florian Heller et al.	Immersion	Mobile
Audio cues	Jing Yang et al.	engagement with object	Mobile
Audio cues	Jinyan Lu et al.	HTC Vive platform with the scene	VR
Audio cues	Bailenson et al.	Audio vs. Audio+Video vs. Audio+Emotibox	VR
Audio cues	Jin et al.	Text vs. Audio	VR, Web
Audio cues	Dicke et al.,	Monophonic vs. Stereophonic vs. Binaural	VR
Audio cues	Skalski and Whitbred	Two-Channel Sound vs. Surround Sound	Web

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Research Question and Novelty

Research Question

01. How does three different cues from the remote/physical user affect the level of co-presence in a MR remote collaboration interface?
02. What are the benefits of mixing cues for MR remote collaboration compared with using each cue alone?

Novelty

1. Design and implementation of a prototype MR system supporting both local and remote collaborators wearing a head mounted display (HMD) and using physical/behavior cues
2. Comparing four combinations of the typical physical/behvior cues (shadow, spatial audio and gesture) in MR remote collaboration
3. Measuring the effect of each and the combinations of visual cues on the co-presence

Experimental Setup

- Three indicators
- Experiment 1. Single-indicator
- Experiment 2. Multi-indicator

Experimental Setup

Three indicators for presence

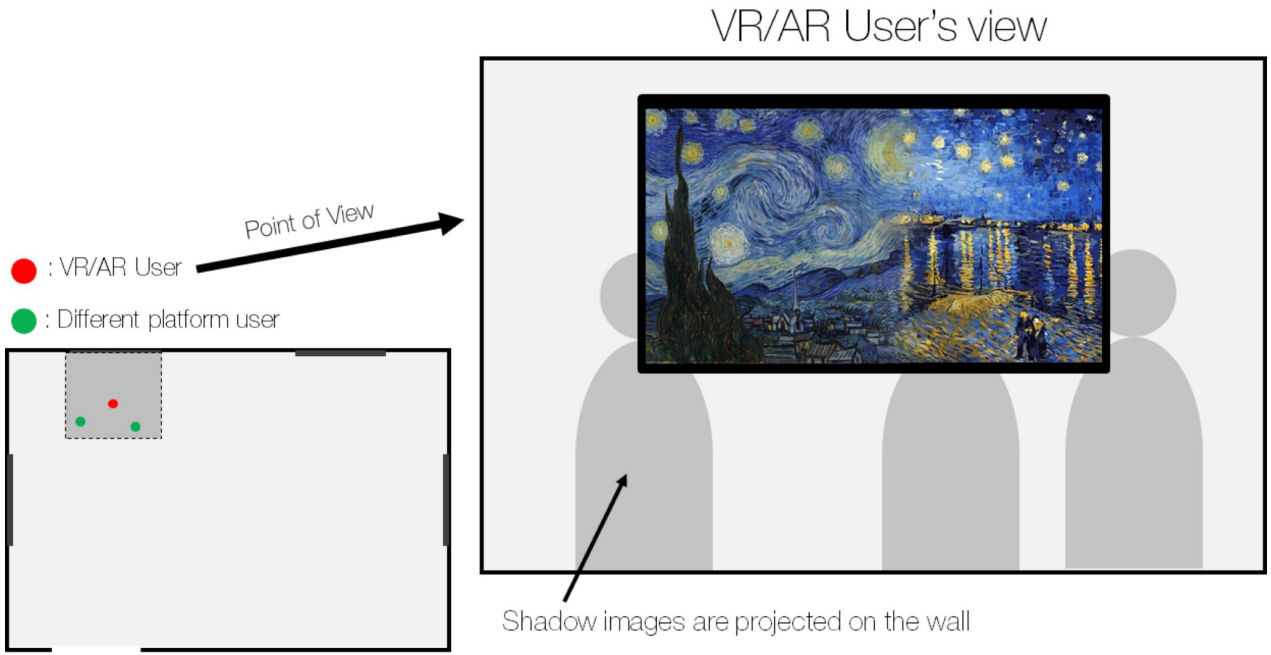
Shadow

Spatial audio

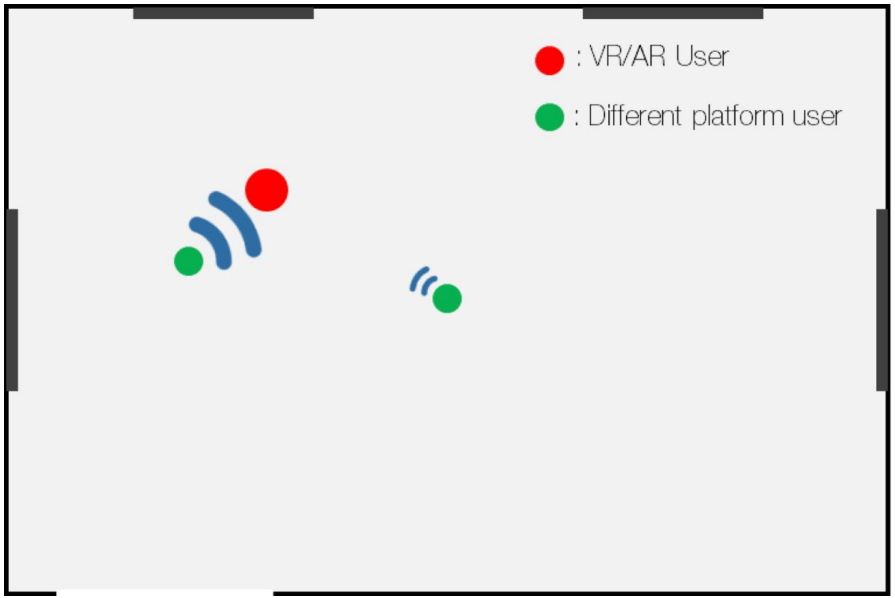
Emotional gesture

Experimental Setup

Indicator: Shadow



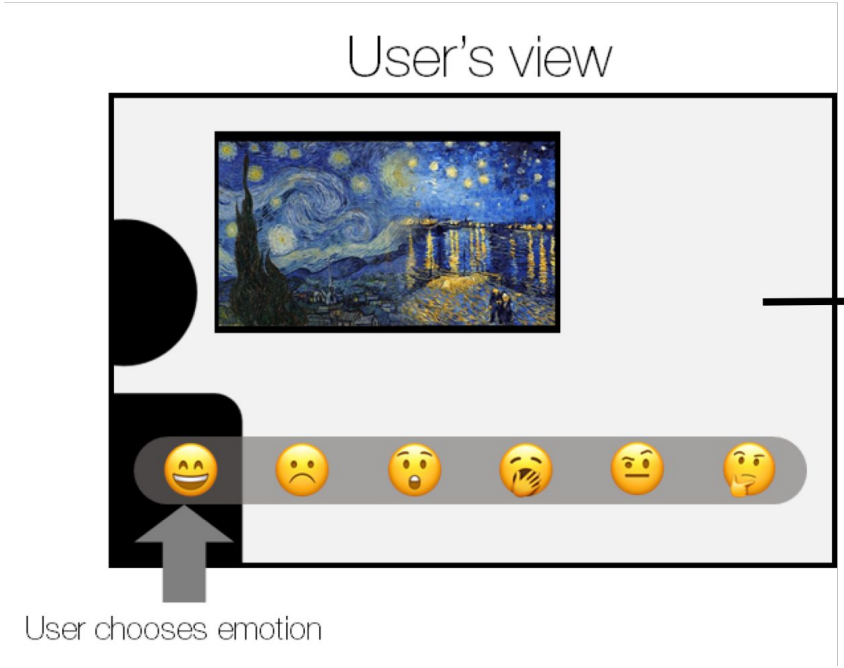
Experimental Setup



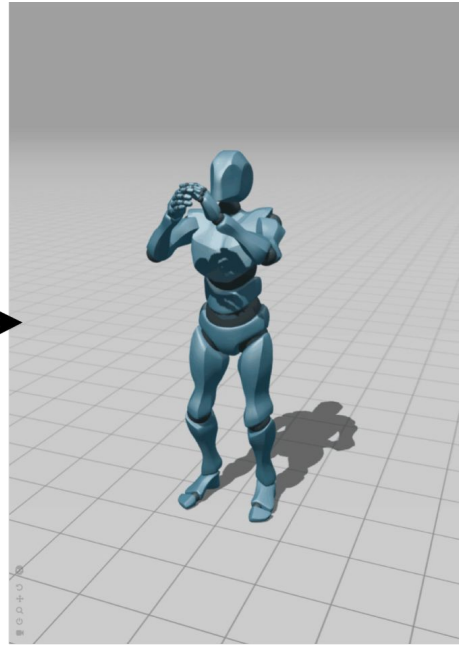
Indicator: 3D Audio

- Play footsteps sound when virtual user moving
- Play rustling sound continuously
- Volume changes according to distance

Experimental Setup



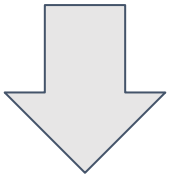
Indicator: Emotional Gesture



Experimental Setup

Experiment 1. Single-indicator

Are there specific **behavioral/physical indicators** in an MR environment that **enhance Human presence without direct communication?**



- Examine whether specific behavioral/physical indicators enhance Human presence
- Compare the effects of indicator on presence in each platforms (AR / VR)

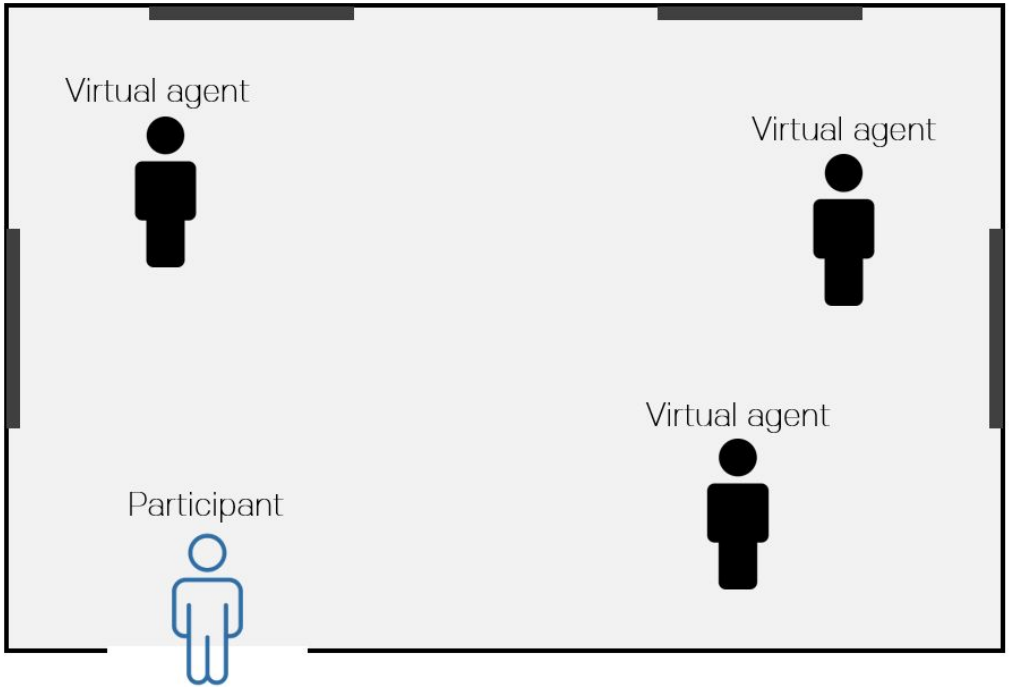
Experimental Setup

Experiment 1. Single-indicator

- Three group of participants for each indicator
- All participants of group experience museum in both AR and VR
- One participant experience museum with 3 virtual agent
- Participants will be informed that virtual agents are real-users

‘Shadow’ group		‘Spatial audio’ group		‘Emotional gesture’ group	
AR	VR	AR	VR	AR	VR

Experimental Setup



Participant (AR/VR)

1

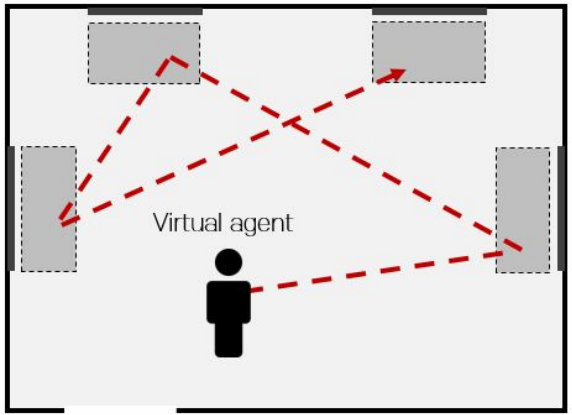
Virtual agent
(3d avatar)

3

Experimental Setup

Virtual agent setting

- Random select destination from the list where virtual object didn't visit
- Move straight to destination
- Stay at the destination for 10s~1min
- When using 'emotional gesture' indicator, virtual agent shows one random gesture at destination



Experimental Setup

Experiment 2. Multi-indicator

- At real, people realize others by multiple cues

  -> Examine whether use of multiple indicators in MR also enhances presence
- Identify best combination of indicators that derive high co-presence

Experimental Setup

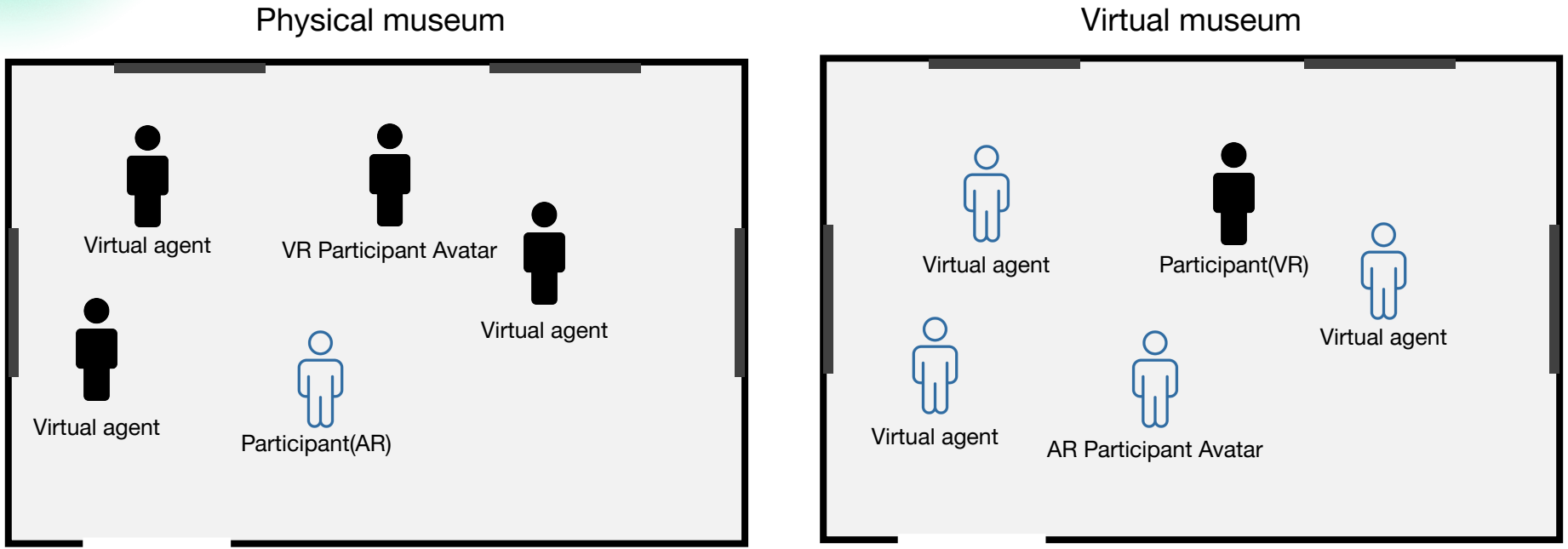
Experiment 2. Multi-indicator

- Test combination of indicators
- Two participants experience museum simultaneously
- One participant use AR in physical museum, and the other use VR in virtual museum
- 3 Virtual agents
- Participants are informed that another 4 avatars are all real person
- Each team experience one from 4 combination of indicators

  - Shadow + Spatial audio
  - Shadow + Emotional gesture
  - Spatial audio + Emotional gesture
  - Shadow + Spatial audio + Emotional gesture

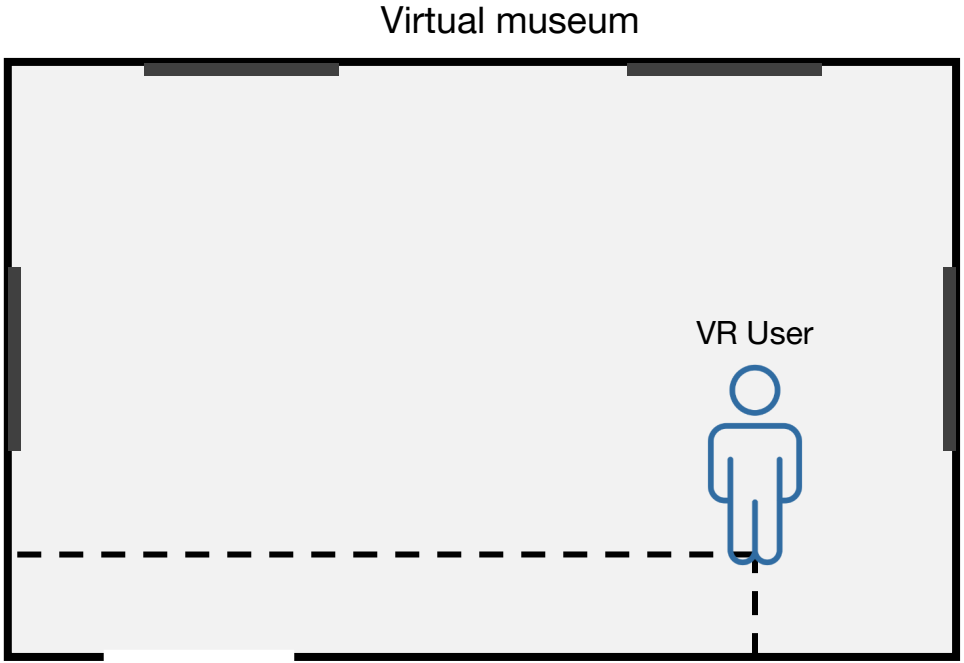
Co-presence in MR Museum

Experimental Setup



Share same map and position of other platform users

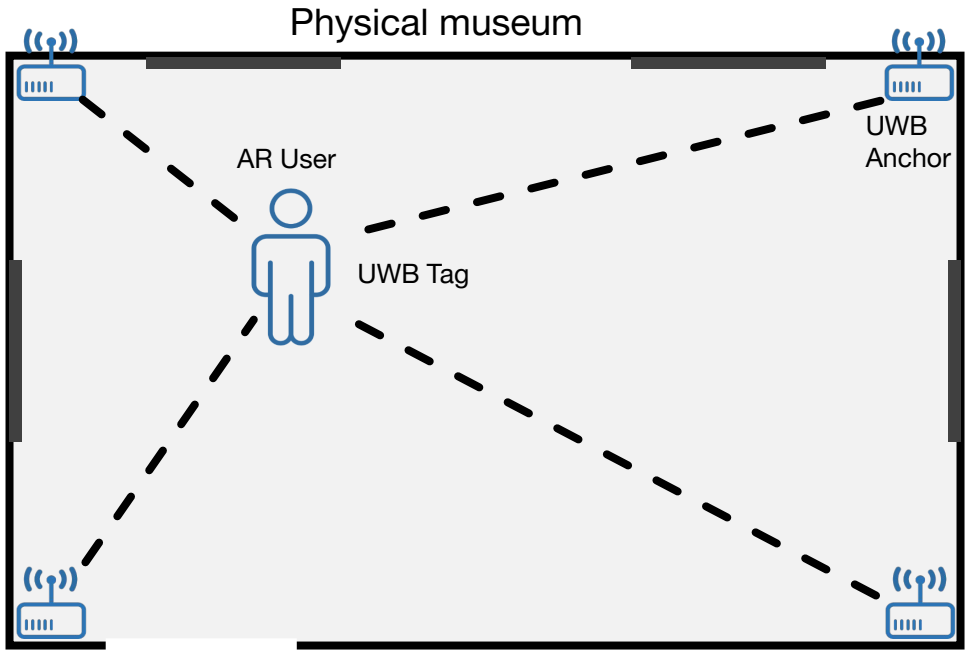
Experimental Setup



- Get user's coordinate from Unity

Real Time Location Server

Experimental Setup



- Get user's position using UWB indoor positioning

Real Time Location Server

Experimental Setup

Why UWB(Ultra-wide Band)?

- High accuracy (~30 cm)
- Almost no interferences
- Identification

Technology	Maximum Range	Maximum Throughput	Accuracy	Advantages	Disadvantages
Wi-Fi	250m outdoor 35m indoor	600 Mbps	m	Widely available, high accuracy does not require complex extra hardware	Prone to noise requires complex processing algorithms
UWB	10~20m	460 Mbps	cm~dm	Immune to interference provides high accuracy	Shorter range, requires extra hardware on different user devices high cost
RFID	200m	1.67 Gbps	dm~m	Consume low power, had wise range	Localization accuracy is low
Bluetooth	100m	24 Mbps	m	High throughput, reception range, low energy consumption	Low localization accuracy, prone to noise
Ultrasound	Couple tens of meters	30 Mbps	cm	Comparatively less absorption	High dependence on sensor placement

Experimental Setup

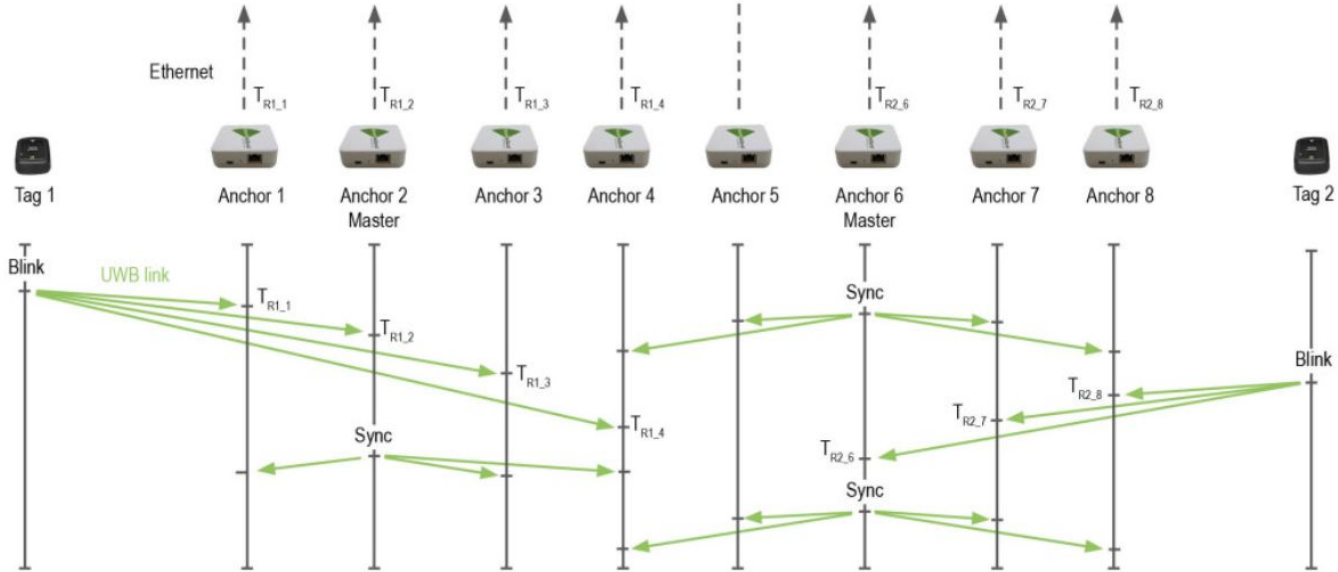
SEWIO

UWB Anchor
‘Seiwo Vista Omni’

UWB Tag
‘Seiwo Leonardo Persional’

Experimental Setup

Time difference of arrival(TDoA)-based algorithms



Experimental Setup

Time difference of arrival(TDoA)-based algorithms

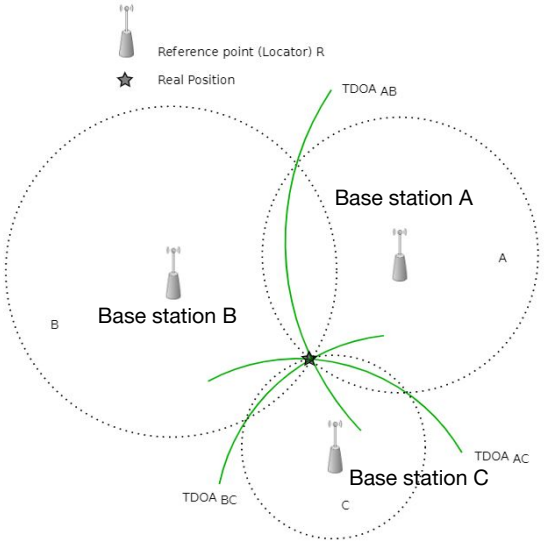


Figure 6. Time difference of arrival (TDoA)-based algorithms.

- Measure the deliver time difference among the target and the multiple base stations

$$T_A: signal\ arrival\ time\ from\ target\ to\ base\ station\ A$$

$$T_B: signal\ arrival\ time\ from\ target\ to\ base\ station\ B$$

- The distance difference from the time difference by multiplying the speed of the signal

$$D_{AB}: v * (T_A - T_B)\ (v: speed\ of\ the\ signal)$$
$$distance\ difference\ among\ the\ target\ and\ basestation\ A, B$$

- Distance difference between any point on hyperbola and focus F, G is always constant.
- The target must be located on the hyperbola which focuses on two base stations
- The intersections of all hyperbolas are likely to be the location of the target

User Study

- Methodology
- Questionnaires
- Evaluation

Constructing User Study

Will co-presence enhanced by exploitation of physical indicators (manifestations) among visitors in virtual and physical world?

Research Question 01) How does three different cues from the remote/physical user affect the level of co-presence in a MR remote collaboration interface?
Research Question 02) What are the benefits of mixing cues for MR remote collaboration compared with using each cue alone?

Constructing User Study

- User Studies carried out to test and compare two VM systems(physical, Virtual), which differ in the devices and environment
- After finishing each trial and the combination trials, we will evaluate their experience and provide qualitative feedback about the cues and system in general
- Measurements We used a within-subject design between different cue conditions, as described above.

1) **Researching** and compiling co-presence/social-existence related research
2) Clarifying the factor structure and **reconstructing the questionnaires**
3) **Verifying the reliability and validity** of the measurement items
4) conducting **statistical analysis** using SPSS/LISREL
5) Additional Questionnaires and interview on its impact on art-viewing environment

User Study: Social Presence and Co-presence

NMM Social Presence Questionnaire (Biocca et al., 2004)

To investigate if the type of physical/behavior cues affected the participants' co-presence in both environments, we will use three sub-scales, Co-presence (CP) of the Networked Mind Measure of Social Presence Questionnaire

originally consists of 18 rating items on a 7-point Likert scale (1: Strongly Disagree~7: Strongly Agree)

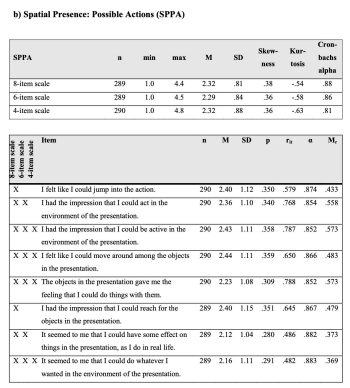
While in the MR Museum environment	Questionnaires (Scale of 1-7)	Variable1	Variable 2
		a=0.74	a=0.82
Mutual Awareness (3 matched pairs)	I hardly noticed that there was a partner.	o	
	The other person didn't realize I was there.	o	
	I could feel the existence of the other party.	o	
	The other person seemed to feel my existence.	o	
Attentional Allocation (4 matched pairs)	I sometimes pretended to pay attention to the other individual.		o
	The other individual sometimes pretended to pay attention to me.		o
	The other individual paid close attention to me		o
	I paid close attention to the other individual.		o
	My partner was easily distracted when other things were going on around us.		o
	I was easily distracted when other things were go- ing on around me.		o
	The other individual tended to ignore me		o
	I tended to ignore the other individual		o

User Study: Spatial presence [Virtual Users Only]

MEC Spatial Presence Questionnaire (Harms et al., 2004)

To study if the different types of physical/behavior cues affected the remote user's sense of being in a remote location or not, we will conduct three sub-scales, the Spatial Situation Model (SSM), the Spatial Presence: Self Location (SPSL), and the Spatial Presence: Possible Actions (SPPA) of the MEC Spatial Presence Questionnaire

consists of 18 rating items on a 5-point Likert scale (1: Fully Disagree~5: Fully Agree)



b) Spatial Presence: Possible Actions (SPPA)

SPPA	n	min	max	M	SD	Skew-ness	Kur-tosis	Cron-bachs alpha
8-item scale	289	1.0	4.4	2.32	.81	.38	-.54	.88
6-item scale	289	1.0	4.5	2.29	.84	.36	-.58	.86
4-item scale	290	1.0	4.8	2.32	.88	.36	-.63	.81

8-item scale 6-item scale 4-item scale	Item	n	M	SD	p	r_{it}	α	M_r
X	I felt like I could jump into the action.	290	2.40	1.12	.350	.579	.874	.433
X X	I had the impression that I could act in the environment of the presentation.	290	2.36	1.10	.340	.768	.854	.558
X X X	I had the impression that I could be active in the environment of the presentation.	290	2.43	1.11	.358	.787	.852	.573
X X X	I felt like I could move around among the objects in the presentation.	290	2.44	1.11	.359	.650	.866	.483
X X X	The objects in the presentation gave me the feeling that I could do things with them.	290	2.23	1.08	.309	.788	.852	.573
X	I had the impression that I could reach for the objects in the presentation.	289	2.40	1.15	.351	.645	.867	.479
X X	It seemed to me that I could have some effect on things in the presentation, as I do in real life.	289	2.12	1.04	.280	.486	.882	.373
X X X	It seemed to me that I could do whatever I wanted in the environment of the presentation.	289	2.16	1.11	.291	.482	.883	.369

a) Spatial Presence: Self Location (SPSL)

SPSL	n	min	max	M	SD	Skew-ness	Kur-tosis	Cron-bachs alpha
8-item scale	290	1.0	5.0	2.38	.91	.50	-.36	.93
6-item scale	290	1.0	5.0	2.37	.94	.52	-.36	.92
4-item scale	290	1.0	5.0	2.33	.99	.56	-.42	.92

8-item scale 6-item scale 4-item scale	Item	n	M	SD	p	r_{it}	α	M_r
X	I had the feeling that I was in the middle of the action rather than merely observing.	290	2.21	1.11	.302	.655	.931	.558
X X	I felt like I was a part of the environment in the presentation.	288	2.17	1.07	.293	.805	.920	.663
X X X	I felt like I was actually there in the environment of the presentation.	288	2.56	1.15	.391	.853	.916	.699
X X	I felt like the objects in the presentation surrounded me.	290	2.72	1.17	.429	.612	.935	.521
X X X	It was as though my true location had shifted into the environment in the presentation.	290	2.32	1.11	.331	.806	.920	.668
X	It seemed as though my self was present in the environment of the presentation.	290	2.64	1.11	.409	.773	.923	.641
X X X	I felt as though I was physically present in the environment of the presentation.	290	2.09	1.07	.272	.801	.921	.664
X X X	It seemed as though I actually took part in the action of the presentation.	289	2.33	1.08	.333	.824	.919	.679

Constructing User Study

1) **Researching** and compiling co-presence/social-existence related research
2) Clarifying the factor structure and **reconstructing the questionnaires**
3) **Verifying the reliability and validity** of the measurement items
4) conducting **statistical analysis** using SPSS/LISREL
5) Additional interview questionnaires on its impact on art-appreciating experience

Questionnaires
Has presence of human-being affected your art-viewing expreience?
Were you more immersed to simulated environment with the presence of human-being?
Do you hope that the museum use the same apporaches as this area into more exhibions frequently?
Was virtual encounter of visitors was as intriguing as the physical encounter
Did you feel comfortable? (what feelings were there when you got the sense of being together?)
Did presence of human-being make you to immerse in the simulated environment?
In what level the ‘Hand gesture’ affected the co-presence?
In what level the 'Spatial-Audio' affected the co-presence?
In what level the 'shadow'' affected the co-presence?
Did each factors made you feel like you were 'with' the people?

Future Application

- Future Applications

Future application

Further Experiment setting and User Study on Usability and Satisfaction on MR Museum Environment

- using the System Usability Scale (SUS) and interview

MR Museum Enterprise

Co-presence in MR

Thank you