

CAADRIA 2025 WORKSHOP PROPOSALS

Email Address:

LO Tian Tian <tt2lo@polyu.edu.hk>

1. Title

Phygital Modular Structure:

A Gamified Virtual Participatory Design System with Tangible Interaction

Keywords: Virtual Reality Interaction, Extended Reality (XR), Participatory Design, Gamification Mechanisms, Modularity

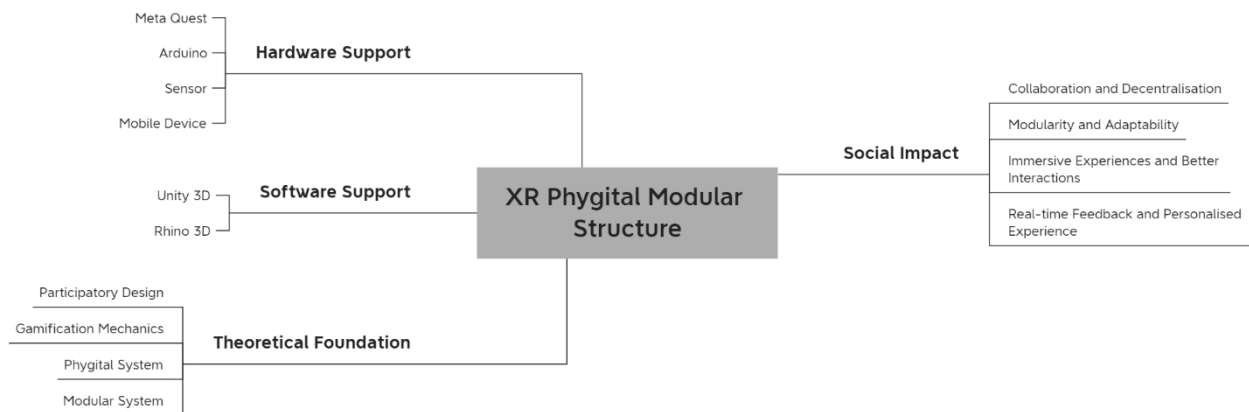
2. Introduction

2.1 Abstract

Integrating gamification mechanisms into participatory design enhances user engagement and feedback effectiveness. This gamified framework facilitates structured communication between designers and non-professionals, optimized by interaction technology. Immersive technology, particularly gesture-based systems, enables real-time engagement with virtual models, though it requires a learning curve and may not visually represent design outcomes as effectively as physical models. The convergence of digital twin and extended reality (XR) technologies within a Phygital system allows seamless interaction and data exchange between virtual and physical models, enriching the gamified environment. This integration supports rapid design modifications through modular construction, enhancing design communication and output capabilities.

The project enables designers to rapidly create customizable XR interactive game scenarios by integrating physical models with digital interfaces. Utilizing modular design and the Unity platform, it allows real-time synchronization with virtual platforms, enhancing accessibility and engagement for participants, including those with limited technical expertise, in exploring modular design possibilities

2.2 Framework



2.2.1 Theoretical Foundation

The integration of participatory design with gamification mechanisms aims to enhance collaboration between designers and non-experts by increasing engagement and motivation. Early studies incorporated game-like elements—such as points, levels, and rewards—into participatory frameworks to encourage active participation and facilitate clearer feedback channels. This approach is particularly beneficial for design processes requiring non-experts' input, where engagement and understanding are crucial. Recent research indicates that gamified participatory design environments stimulate creativity and increase participants' investment in design outcomes, leading to more robust and innovative solutions. However, challenges remain, as virtual environments can create cognitive barriers for non-professionals due to the abstract nature of digital interfaces and the learning curve of complex software. Extended Reality (XR) and Digital Twin technologies have been introduced to address these challenges, offering immersive, interactive experiences and real-time mirroring of physical and virtual environments. Despite their potential, these technologies require further refinement due to limitations such as intensive training needs and insufficient accuracy.

Phygital systems, combining XR, Digital Twin, and physical sensors, offer a promising solution by minimizing

the learning curve and enabling intuitive interaction through natural gesture-based interfaces, thus reducing cognitive load and enhancing user engagement with virtual models.

2.2.2 Social Impact

Collaboration and Decentralisation: XR technology facilitates real-time collaboration in virtual environments for geographically dispersed teams. Modular components and gamification promote active idea contribution, fostering decentralized decision-making and enhancing team cohesion and creativity.

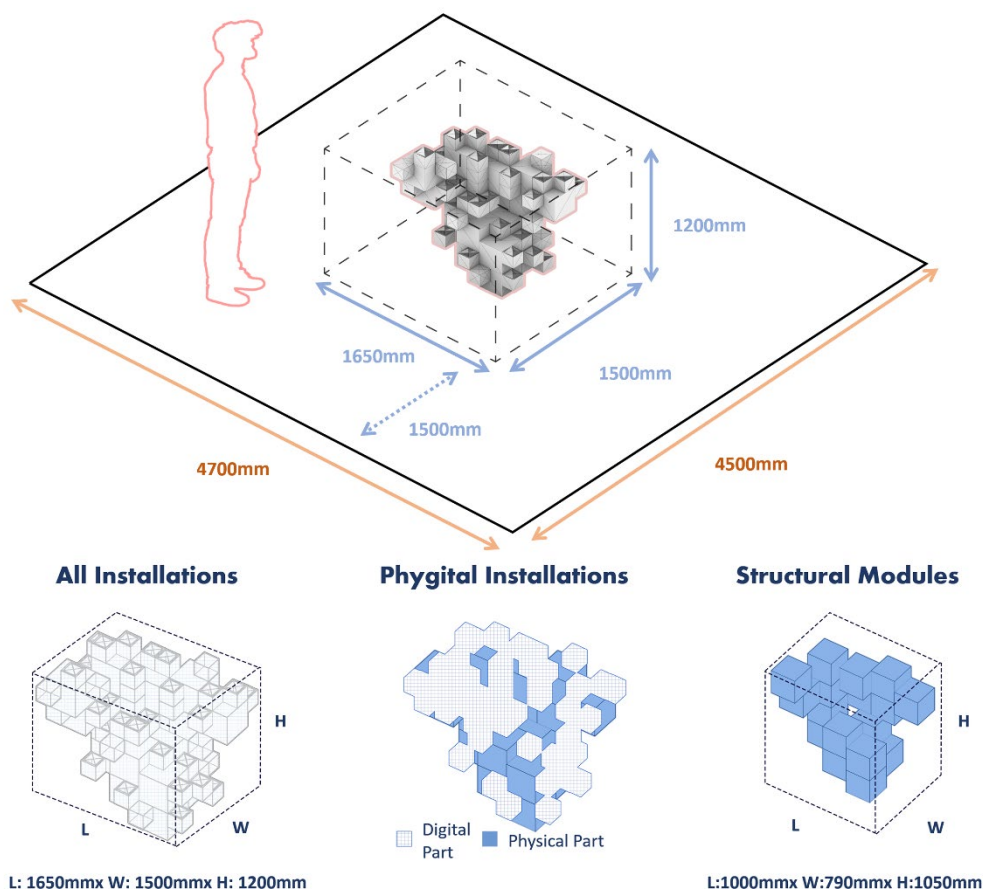
Modularity and Adaptability: Modular design supports rapid iteration and adaptation to evolving needs. Gamification allows participants to test and modify modules in a secure virtual environment, increasing design flexibility and adaptability.

Immersive Experiences and Better Interactions: XR technology provides immersive experiences for intuitive understanding and interaction with design solutions. Gamification enables users to engage with virtual models through natural gestures, enhancing user experience and engagement.

Real-time Feedback and Personalised Experience: Real-time feedback allows immediate observation of design changes, facilitating rapid iteration. Gamification offers personalized experiences based on user behaviour, enhancing engagement and satisfaction.

3. Workshop Outcome

The culminating task of this project involves the development of an interactive system that integrates both physical and virtual interactions. The physical component entails the construction of a modular model, approximately 165 cm in length, 150 cm in width, and 120 cm in height, to be displayed within an exhibition hall. This model is composed of various modules of differing dimensions. Surrounding the model, a 160 cm wide area is designated for participants to engage in virtual interactions. Within the installation, certain modules serve as structural supports for the entire model, measuring approximately 100 cm by 79 cm by 105 cm, while other detachable modules function as interactive game components. The virtual interface facilitates the creation of a game system designed for multiple participants. Participants can engage with the game using XR devices, such as Meta Quest, or mobile devices, with interactive data being transmitted and recorded in real-time on a computer. This integration of virtual and physical elements through digital twin technology ensures a seamless and real-time participatory design process. Furthermore, user operations within the virtual environment are synchronized instantaneously with the real-world setup.



4. Content

Day 1: Introduction to Participatory Design and Gamification

Morning Session: Lecture

Introduction to Participatory Design, an overview of the framework and process
Introduce the Case with a focus on XR techniques

Afternoon Session: Lecture and Discussion

Introduction to Gamification include Mechanics and evaluation
Group Formation and Discussion

Day 2: Building Interactive MR Platforms with Unity

Morning Session: Set Up the XR platform

Download and Installation the Unity Platform
Overview of building interactive XR platform

Afternoon Session: Game System Development

Interaction settings and game system development
Exploration of gesture control and interactive events with Meta Quest

Day 3: Sensor Integration with Arduino

Morning Session: Introducing Sensor Setting Parameters

Installation and testing of Arduino and sensors
Sensor categorization and selection

Afternoon Session: Designing Modules

Development of preliminary models through data testing
Designing physical modules based on game mechanics

Day 4: Model Testing and Practical Application

Morning Session: Data streaming

Real-time Sensor Data Communication
Using Unity to communicate sensor data with computers

Afternoon Session: Testing and Feedback

Cross-Group Testing and Feedback
Group discussions on modifications for future participatory design

5. Organizers

5.1 Number of People:

Minimum and Maximum number of workshop participants: 5-8

5.2 Requirements:

Required Hardware: Laptop (better with Windows)

Required Software: Unity, Arduino Uni

5.3 Equipment from the Workshop Instructor:

Meta Quest3 : 3

Arduino Uno board and Sensor: Suitable number

Some physical modules for teaching: Suitable number

5.4 Hardware and Software Description

5.4.1 Software Requirements (to be installed by participants):

Rhino

Description: A 3D modeling software widely used in industrial architecture

Workshop Use: use Rhino to design modular structures

Unity 3D

Description: A widely used cross-platform game engine with wide variety of plugins.

Workshop Use: Participants will use Unity 3D to create simple game frameworks

Arduino IDE

Description: An open-source software application used for writing, editing, compiling, and uploading code to Arduino boards.

Workshop Use: Participants will write code to implement simple sensor detection functions.

Meta Quest Developer Hub

Description: A application designed specifically for developers to streamline the development, testing, and deployment of MR content on Meta Quest devices

Workshop Use: Use Developer Hub to develop, test, and deploy XR experiences on devices.

Another SDK in Unity

1. *Meta XR ALL in one SDK*

Description: A development toolkit specifically designed to support Meta Quest devices

Workshop Use: Integrates XR features .

2. *Mirror in Unity*

Description: An open-source networking framework for Unity

Workshop Use: Create multiplayer games and applications.

3. *Ardity*

Description: A Unity plugin designed to establish serial communication between Unity and Arduino.

Workshop Use: Use Ardity to read sensor data from Arduino within Unity or control Arduino-connected hardware devices via Unity.

5.4.2 Hardware (provided by Our team)

Meta Quest 3

Description: Meta Quest 3 is an all-in-one mixed reality (MR) independently headset

Use in Workshop: Use the Quest 3 headset to experience the entire participatory design process, and collaborate with others to complete the design workflow.

Arduino Uno

Description: An open-source electronic development board widely used for electronic prototyping.

Use in Workshop: Participants will use Arduino Uno to design sensor-based mechanisms.

Hardware and Software Description

Hall Sensor

Description: A sensor that detects the presence of a magnetic field

Use in Workshop: Participants will manually connect the Hall sensor circuit and experiment with the sensor and related components to create a trigger mechanism

6. List of Confirmed Instructor

Dr. Sky Lo Tian Tian  [0000-0002-1992-0777](https://orcid.org/0000-0002-1992-0777)

Academic qualifications:

- 08/2015 – 06/2018 PhD in Architecture, Receiver of Victoria Doctorate Scholarship, Victoria University of Wellington, New Zealand
- 06/2006 – 06/2011 Passed RIBA (1&2), Dissertation in NUS Publication, National University of Singapore (NUS), Singapore

Present academic position:

- 09/2022-Present Assistant Professor, Department of Environment and Interior Design (EID), School of Design, The Hong Kong Polytechnic University

Previous relevant research work

- 2024-2026 Principal Investigator, "Developing an Extended Reality (XR) Gamified Participatory Urban Furniture Design System using Discrete Bamboo Fabrication" funded by General Research Fund (GRF). HKD\$1,200,000
- 2023-2025 Principal Investigator, " tPAC: Phygital-Aided Construction System based on Modular Customizable Timber Fabrication for Urban Housing" funded by School Collaborative Research Fund with Non-local Institutions. HKD\$400,000
- 2023-2024 Principal Investigator, " The Meta Archive: A Platform for Virtual Presentation and 3D Model Archiving" funded by Configreality Technology Limited (Collaborative). HKD\$280,000
- 2023-2025 Principal Investigator, " Phygital Recycling: Development of a Gamified Interactive XR Structure to Enhance the Participation of Recycling" funded by Start-up Fund for New Recruits. HKD\$350,000
- 2023-2025 Principal Investigator, " Phygital Healing: A Study on the Effects on Human Emotions through Mixed Reality (MR) Interactive Hybrid Environment" funded by Departmental Start-up Fund. HKD\$150,000

Publication records Section A:

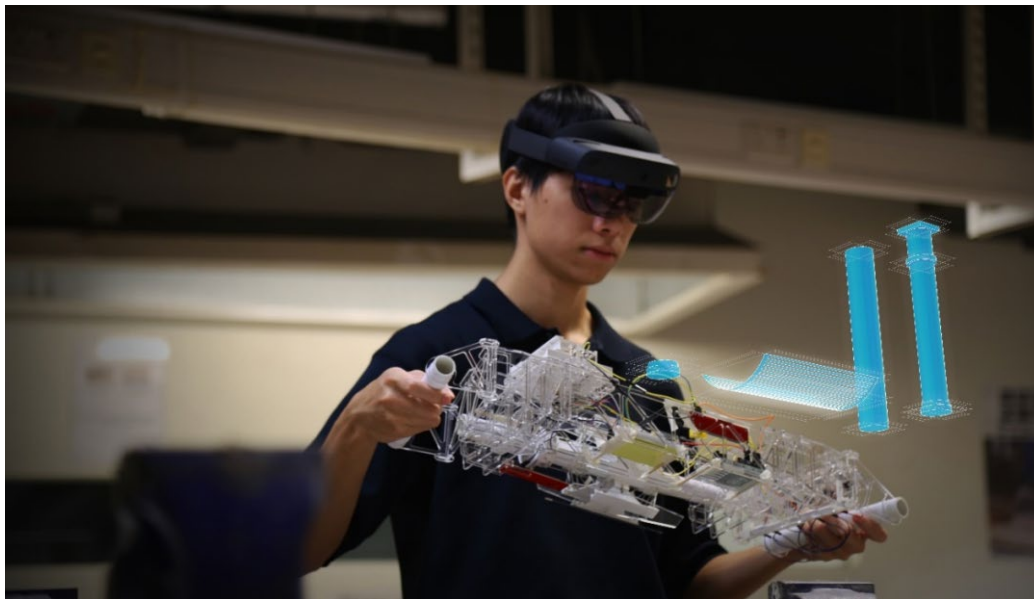
1. Corresponding Author, Research Supervisor
X.M. Guo, D.C. Wang, T.T. Lo* (2024): Historical architecture pedagogy meets virtual technologies: A comparative case study. *Educ Inf Technol*. <https://doi.org/10.1007/s10639-023-12420-1>
2. Corresponding Author, Research Supervisor
X.N. Gao, T.T. Lo*, X.M. Guo (2023): M-StruGAN: An Automatic 2D-Plan Generation System under Mixed Structural Constraints for Homestays. *Sustainability*. 15, 9, 7126.
3. Corresponding Author, Research Supervisor
W.Q. Li, T.T. Lo*, X.M. Guo (2023): Exploring the Application of the Digital Gamification Mechanisms to the Experience of Physical Architectural Exhibitions. *HUMAN-CENTRIC: Proceedings of the 28th CAADRIA Conference*. Ahmedabad, p. 717–726 10 p.
4. Corresponding Author, Research Supervisor
X.M. Guo, Y.W. Yang, Z.Y. Cheng, Q. Wu, C.J. Li, T.T. Lo*, F.K. Chen (2021): Spatial Social Interaction: An Explanatory Framework of Urban Space Vitality and its Preliminary Verification. *Cities*, Elsevier. <https://doi.org/10.1016/j.cities.2021.103487>
5. Corresponding Author, Research Supervisor
K.N. Sun, T.T. Lo*, X.M. Guo (2022): Digital Construction of Bamboo Architecture based on Multitechnology Cooperation: Constructing a New Parameterized Digital Construction Workflow of Bamboo Architecture from Traditional Bamboo Construction Technology, Post Carbon - Proceedings of the 27th CAADRIA Conference, The University of Sydney, 9 - 15 April 2022
6. Corresponding Author, Research Supervisor
C.H. Lin, T.T. Lo*, X.C. Hu (2021): Exploring the Possibilities of a Virtual-Reality-Aided Architectural Design System, Towards a new, configurable architecture - Proceedings of the 39th eCAADe Conference - Volume 2, University of Novi Sad, Novi Sad, Serbia, 8-10 September 2021, pp. 555-564

Profile:

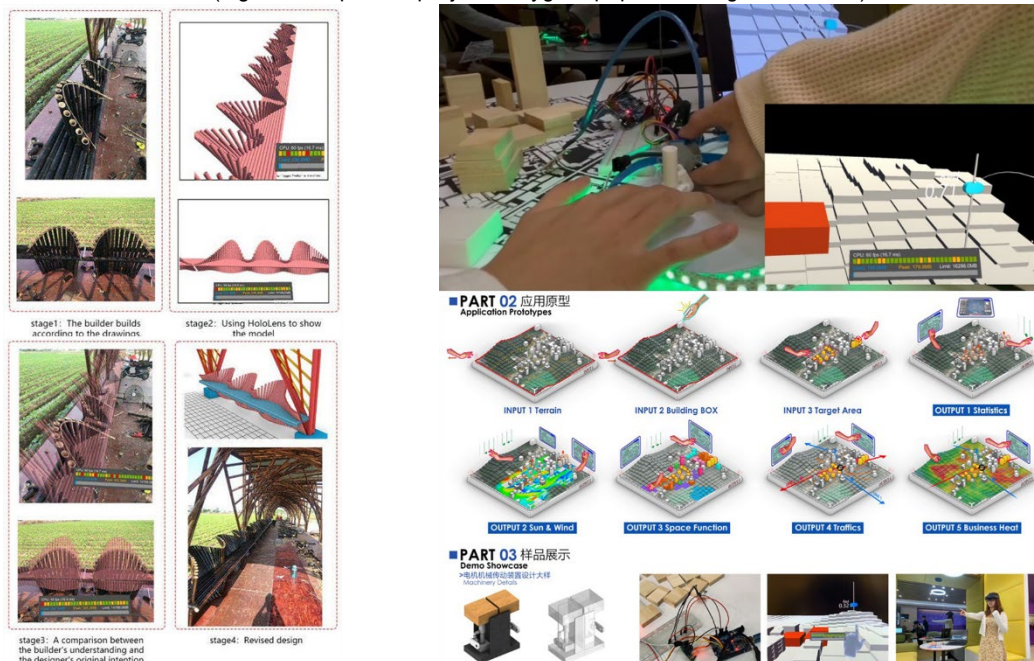
Sky Lo is a Hong Kong-born Singaporean appointed as an Assistant Professor in the School of Design. He was previously employed at the Harbin Institute of Technology (Shenzhen). During his doctoral study, he was awarded a full doctoral scholarship by the Chinese University of Hong Kong and the Victoria University of Wellington. His main research area is the bottom-up human-centred architectural design concept, using XR, BIM, and gamification to create an interactive environment. He is currently working on "interactive reality", transdisciplinary research on the interaction between the virtual and the physical environment. His work integrates design and technology to bridge the gap between the city and the rural setting. He has published numerous papers on transdisciplinary research towards interactive design and is now one of the various high-impacted academic organizations' primary committee members and reviewers. <https://orcid.org/0000-0002-1992-0777>

7. Previous Work

Physical Space Narration



(Figure 1: Capstone project: Phygital paper crafting-Tom Chow)



(Figure 2: left: Exploration of Auxiliary Construction of Augmented Reality, Right: workshop2021- Cityscope+)

8. Affiliated Institutions

The Hong Kong Polytechnic University (PolyU) :

The Hong Kong Polytechnic University (PolyU) is a public research university in Hung Hom, Kowloon, Hong Kong. The university is one of the eight government-funded degree-granting tertiary institutions in Hong Kong. Founded in 1937 as the first Government Trade School, it is the first institution to provide technical education in Hong Kong. In 1994, the Legislative Council of Hong Kong passed a bill which granted the former Hong Kong Polytechnic official university status. PolyU consists of 8 faculties and schools, offering programmes covering applied science, business, construction, environment, engineering, social science, health, humanities, design, hotel and tourism management.

9. Contact information

Dr. Sky Lo Tian Tian.

The Hong Kong Polytechnic University tt2lo@polyu.edu.hk

CAADRIA2025 Workshop

Call for participants

- As part of the conference, CAADRIA offers a series of exciting workshops around a range of cutting-edge topics and methodologies in Architectural Informatics. Led by expert instructors from around the world, the workshops are aimed at students, researchers and young professionals interested in extending their knowledge and skills in the field of computational processes in architecture and urbanism.
- **Participant applications will open on January 6th.**
- Applications will close when overall number of participants is reached to capacity.
- Assignments to the workshop groups will be made by the organizing committee based on the preferences at the time of application and the capacity of each group.
- Registration with CAADRIA is required to participate the workshop.
- Workshop results will be presented and exhibited during the CAADRIA conference.



AI Fabrication Modeling

Victor Beomseung Jo



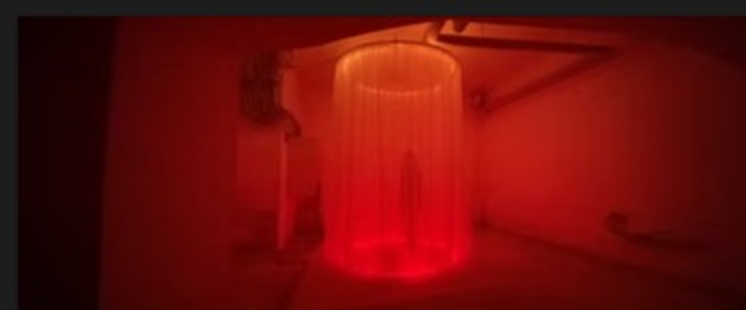
Ceramic Walls AI

Yuko Ishizu, Tomohiro Inoue, Junichiro Horikawa



Collaborative Robotic Assembly

Arastoo Khajeheh, Nicolas Rogeau



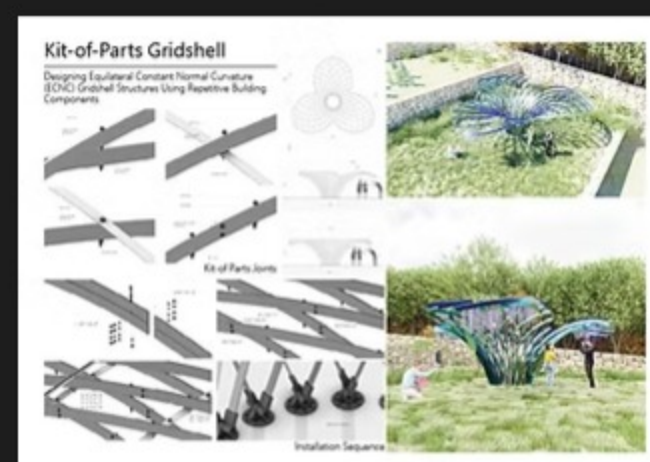
Crafting Informational Atmospheres

Carlos Garcia Fernandez, Burcu Nimet Dumlu, Ismael Raza, Masaya Shimizu, Yufan Zhu, Takatoshi Yoshida, Kouta Minamizawa



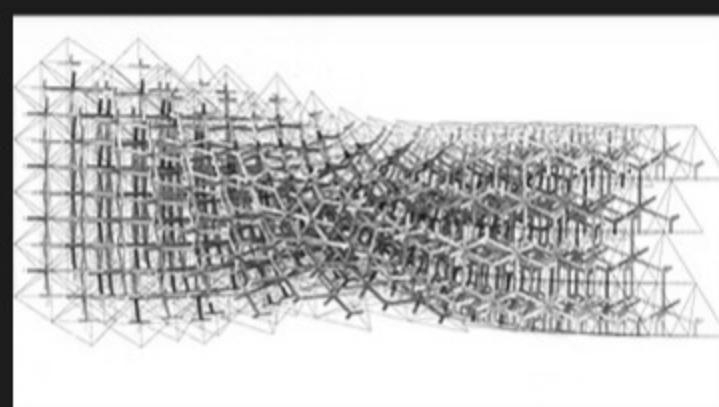
Crystallizing Data

Ondrej Ciganik, Hugo Fekar, Daniel Svitak, Adam Varga



Kit-of Parts Gridshell

Haotian Man, Dr. Zongshuai Wan, Prof. Dr. Eike Schling



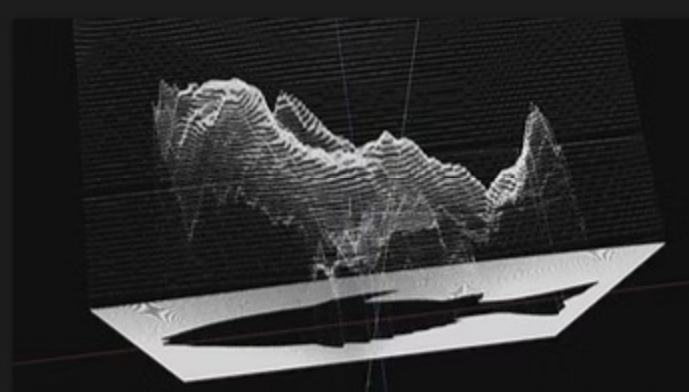
NURBS Volume Crystallography

Satoru Sugihara



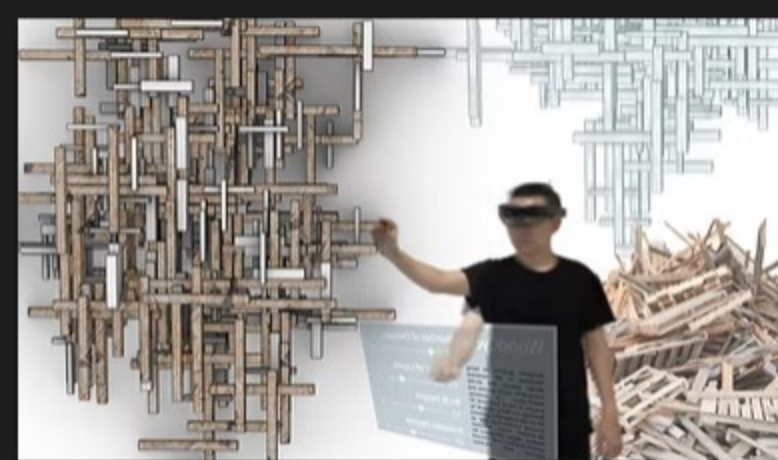
Phygital Modular Structure

Sky Lo Tian Tian



Space Pointillism

Risa Kagami, Ayaka Sato, Anna Yamazaki



WoodCycle

Eri Sumitomo, Yang Song

Schedule

2024

- Aug. 24th. Start of open call for workshop proposals
- Nov. 7th. Deadline of workshop proposals
- Nov. 12th. Notification of workshop proposal selection (to be delayed)

2025

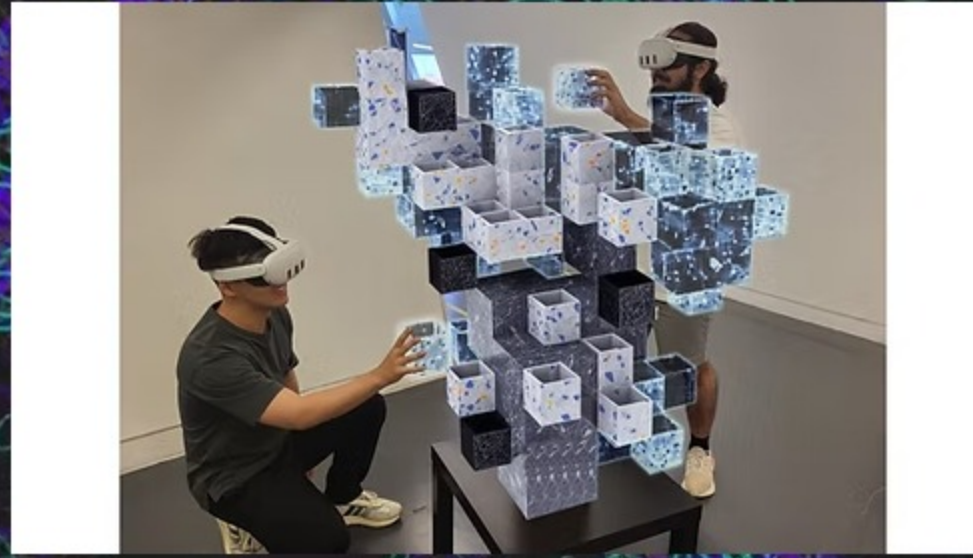
- Jan. 6th. Start of application for participants
- Jan. 20th. Deadline for application for participants
- Jan. 31st. Notification of participants
- Feb. 20th - Mar. 22nd, 2025. Preparation period(Online) [Pre-technical workshop, development of Installation design, etc.]
- Mar. 22nd - Mar. 25th, 2025. Workshop(On-site)
- Mar. 26th, 2025. Presentation before the CAADRIA opening
- Mar. 26th - 28th, 2025. Evaluation period
- Mar. 28th, 2025. Announcement of evaluation results (tallied in the morning, announced in the evening during the closing ceremony on the 28th)
- Mar. 29th, 2025. Dismantling of exhibits (after the technical tour)

	Date		Time	
Day1	3/22	Sat	8:00 ~ 18:00	Production Hours
			19:00 ~ 22:00	Round table session
Day2	3/23	Sun	8:00 ~ 18:00	Production Hours
			19:00 ~ 22:00	Round table session
Day3	3/24	Mon	8:00 ~ 18:00	Production Hours
			19:00 ~ 22:00	Round table session
Day4	3/25	Tue	8:00 ~ 18:00	Production Hours

Location

Faculty of Engineering Bldg. 1, the University of Tokyo

CAADRIA2025 Workshop W10: Phygital Modular Structure



Offered by
Sky Lo Tian Tian



CAADRIA 2025 WORKSHOP PROPOSALS

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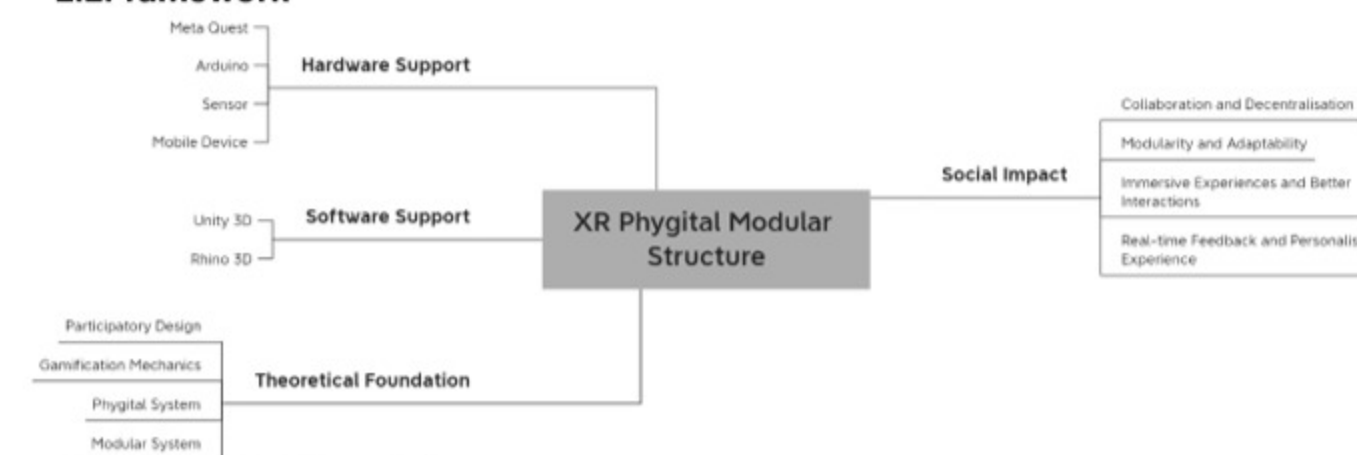
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2.2 Framework



2.2.1 Theoretical Foundation

The integration of participatory design with gamification mechanisms aims to enhance collaboration between designers and non-experts by increasing engagement and motivation. Early studies incorporated game-like elements—such as points, levels, and rewards—into participatory frameworks to encourage active participation and facilitate clearer feedback channels. This approach is particularly beneficial for design processes requiring non-experts' input, where engagement and understanding are crucial. Recent research indicates that gamified participatory design environments stimulate creativity and increase participants' investment in design outcomes, leading to more robust and innovative solutions. However, challenges remain, as virtual environments can create cognitive barriers for non-professionals due to the abstract nature of digital interfaces and the learning curve of complex software. Extended Reality (XR) and Digital Twin technologies have been introduced to address these challenges, offering immersive, interactive experiences and real-time mirroring of physical and virtual environments. Despite their potential, these technologies require further refinement due to limitations such as intensive training needs and insufficient accuracy.

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CAADRIA
W10

