



Decentralized Governance for Virtual Community(DeGov4VC): Optimal Policy Design of Human-plant Symbiosis Co-creation

Yan Xiang

Shanghai Jiao Tong University
Shanghai, China
yanxiang@sjtu.edu.cn

Qianhui Fan

Goldsmiths University of London
London, United Kingdom
qfan001@gold.ac.uk

Kejiang Qian

King's College London
London, United Kingdom
kejiang.qian@kcl.ac.uk

Jiajie Li

Massachusetts Institute of Technology
Cambridge, United States
jiajie@mit.edu

Yuying Tang

Tsinghua University and Politecnico
di Milano
Beijing and Milan, China and Italy
tty21@mails.tsinghua.edu.cn

Ze Gao*

Hong Kong University of Science and
Technology
Hong Kong, Hong Kong SAR, China
zgaoap@connect.ust.hk

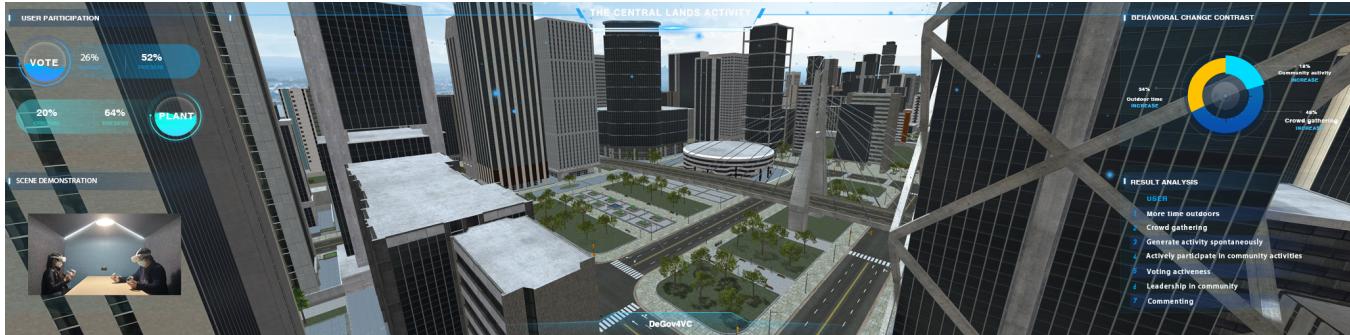


Figure 1: Human-plant Symbiosis Scenario Using the DeGov4VC Platform Interface.

ABSTRACT

Does the decentralized nature of user behavior in interactive virtual communities help create rules promoting user engagement? Through scenarios like planting, this framework suggests a new paradigm for mutual influence that allows users to impact communities' political decisions. Sixteen participants in the first round of interviews were involved in the framework's creation. Then we developed and implemented our framework in the community with the help of other stakeholders. This proof-of-concept creates user groups using information from users' daily activities as input and grows the green plants in a virtual environment. Finally, we involved AI agents and stakeholders in the framework test and iterations. Our study's user evaluation of a few key stakeholders demonstrates how our strategy enhances user viscosity and experience. Via human-planting ecosystems in a virtual community, this research gives a fresh viewpoint on decentralized governance and

an engaging method for co-creating interactive ecological communities.

CCS CONCEPTS

- Human-centered computing → Human computer interaction (HCI); Interactive systems and tools; Empirical studies in HCI; Virtual reality.

KEYWORDS

Interactive System, VR, Co-creation, Virtual Community, Decentralized, Agent-based Simulation

ACM Reference Format:

Yan Xiang, Qianhui Fan, Kejiang Qian, Jiajie Li, Yuying Tang, and Ze Gao. 2023. Decentralized Governance for Virtual Community(DeGov4VC): Optimal Policy Design of Human-plant Symbiosis Co-creation. In *Designing Interactive Systems Conference (DIS Companion '23)*, July 10–14, 2023, Pittsburgh, PA, USA. ACM, New York, NY, USA, 6 pages. <https://doi.org/10.1145/3563703.3596621>

*Ze Gao is the corresponding author.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than the author(s) must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.

DIS Companion '23, July 10–14, 2023, Pittsburgh, PA, USA

© 2023 Copyright held by the owner/author(s). Publication rights licensed to ACM. ACM ISBN 978-1-4503-9898-5/23/07...\$15.00
<https://doi.org/10.1145/3563703.3596621>

1 INTRODUCTION

In recent years, how to promote users' interactive co-creation behavior in a VR approach and better engage users in the co-decision-making process in online communities is becoming a focus of attention [22, 38]. New methods of involving users in the interactive co-creation process have proven necessary to ensure the creativity and longevity of communities [8, 17]. Many studies have pointed



Figure 2: Users or AI Agents Plants in the Virtual Community by Simulating. From Left to Right: Growing Plants From Sapling to a Tree.

out that this way of co-creation can provide value to participants and communities engaged in the policy-making process [1, 31]. Various scenarios need co-creation with users' participation in developing communities [25].

In the development of communities, many scenarios need co-creation with users' participation [3]. Recent HCI research promotes symbiosis with plants as an integral approach to the development of communities [2, 13, 21]. Communities in which can act as one system or as a collection of one or more continuously evolving and changing systems. In this, the relationship between plants and people is mutually beneficial and is in a dynamic state of change, in which the process of human participation and co-creation becomes important. In virtual and physical communities, if interactive co-creation processes are to engage and support cooperative symbiosis with nature, we believe they must be placed in such combinations and decision-making processes.

Therefore, how can users be encouraged to engage in public activities and participate in the decision-making process in the community? Specifically, what gathering forms of decentralized governance in virtual and physical communities can better promote the interactive co-creation process, taking human-plant symbiosis in both virtual and physical nature as a scenario, have been significant research problems. Thus, our research contributes as follows:

- Promote a decentralized approach to governance, helping people gain a new concept of decentralized decision-making and a more desirable interactive co-creation community.
- Create an interactive VR co-creation platform, allowing users to perceive community change through voting. Taking human-plant symbiosis as one of the various scenarios, we emphasize creativity in the design process.
- Design a framework in the interactive decision-making process through simulation to assist stakeholders with co-design in the virtual community and evaluate co-design impact through agent-based simulation.

2 RELATED WORKS

Decentralized governance and Decentralized Autonomous Organizations(DAOs) are innovative approaches that can enhance decision-making processes and promote community collaboration. As a new form of decentralized governance, a DAO holds the community members' interests and enforces a set of shared rules assigned in

code [11]. Its purpose is to balance and optimize the interests of both individuals and the community [6].

These groundbreaking concepts have received increasing attention in research communities, particularly in the field of HCI. With a collective decision-making structure, they naturally align with the principles of co-creation, empowering participatory design processes to actively engage in collaborative decision-making. Elsden et al. [12] arguably identified the immense potential of these technologies in engaging participants and facilitating HCI design with blockchain technology. Besides, interactive tools have the capacity to leverage their power, enabling even greater engagement and participation from individuals and communities. By employing an interactive interface, decentralized governance can enhance the understanding of user needs by involving the public in the design decision-making process [37].

In recent years, there has been a growing interest in the role of community and co-creation in VR [33]. Various studies aim to explore the current research on VR community and co-creation in HCI and its implications for future research [3, 29]. Some examine the role of community design in VR and how it can enhance the user experience by conducting a case study of a VR community design project and found that community involvement increased the engagement and satisfaction of users [28]. While others propose a design framework for co-creation in VR, which emphasizes the importance of collaboration between designers and users, and highlights the importance of user involvement in the design process [7], revealing that co-creation can lead to more engaging and user-centered experiences.

The integration of VR technology into co-creation provides more immersive and interactive experiences for participants [32]. Imottesjo and Kain [18] presented a 3D modeling platform combining web-based VR and mobile augmented reality for urban co-design, emphasizing the necessity of engaging diverse stakeholders and simulating design impact in public space design. Simulation plays a vital role in this process, allowing participants to explore various decision-making outcomes and evaluate the potential impact of proposed changes within the decentralized co-creation system. An agent-based simulation [26] is widely recognized as one of the most effective and popular simulation technologies for studying complex socio-environmental systems and human decision-making, e.g., 3D crowd simulation by Belief–desire–intention(BDI) model [34], and decentralized governance simulation in proof-of-stake blockchain system[24].

Table 1: Co-design Workflow.

Co-design Phase	Stakeholders	Activity	Aim
Phase1:Concept generation	First round eight participants	User interview	Collect and summary what users expect in our interactive system.
Phase2:Framework Creation	Community,government, and designers	System design	Develop and implement framework in online and offline community.
Phase3:Test and Iteration	Community, AI agents, and government	User evaluation	Verify that our interactive system improves user viscosity and user experience in more scenarios.

Although various literature proves that co-creation in VR allows remote participants to collaborate in shared virtual environments, some challenging problems, such as incentivizing public engagement, facilitating decision-making, and evaluating co-creation impacts, are still pending. Decentralized governance and agent-based simulation can provide a significant chance to address these challenges and actualize the full potential of bottom-up involvement in virtual community design. These approaches pave the way for more inclusive and effective virtual community design processes.

3 CONCEPT AND DESIGN PRINCIPLES

3.1 Concept

This study focuses on two main aspects: human-machine collaboration and decentralized governance, with the aim of facilitating web communities' participation in decision-making and interactive co-creation. The objective of this paper is to provide both an artistic and computational exploration of potential future interfaces that are co-created by users and AI agents. Additionally, it delves into the realm of using plant growth as a case study to examine the dynamics of virtual and physical communities.

In this context, users are considered members of both the virtual and physical communities, and their behavior within the virtual community has tangible effects on the properties of the physical community. Conversely, real-time updates from the physical community are reflected within the virtual community. This interconnectedness underscores the importance of co-creation and co-decision-making in fostering a sense of interactivity and mutual influence between the two domains. To realize these objectives, the study proposes a framework that establishes a connection between users, AI agents, and a design framework. This framework serves as the basis for constructing an independent virtual art community. Through this framework, a new virtual interface will be created within the collaborative and co-creative virtual reality (VR) realm[15].

By leveraging the potential of human-machine collaboration and decentralized governance, the study seeks to empower web communities to actively participate in decision-making processes and engage in interactive co-creation. The artistic and computational exploration of future interfaces co-created by users and AI agents adds a visionary dimension to the research. Furthermore, the investigation of plant growth as a case study provides insights into the intricate dynamics of virtual and physical communities, highlighting the potential for cross-pollination and mutual influence.

Ultimately, the study's proposed framework and the subsequent creation of a new virtual interface in the co-creative VR realm aim to foster a collaborative and interactive environment where users can actively engage with AI agents and participate in the construction of a virtual art community. This research contributes to the ongoing exploration of innovative ways to enhance web communities' decision-making capabilities and their potential for co-creative endeavors in both virtual and physical realms.

3.2 Design Principles

Our design principles for the interactive co-design system are implemented through the following key aspects:

- **Decentralization:** The design philosophy of our framework revolves around decentralization[35]. Unlike conventional frameworks that adopt a top-down approach, our system takes a bottom-up perspective, transforming the decision-making process into a collective behavior. By distributing decision-making power among the community members, we aim to foster a sense of ownership and collaboration within the design process.
- **Scenarios:** To illustrate the decision-making dynamics between the community and users, we utilize the symbiotic scenario of humans and plants as a design case. This scenario serves as a context for exploring how decisions can be made within the community based on expected behaviors and various interactions between users and the natural world. By examining this scenario, we can uncover insights into the complex relationship between virtual and physical communities.
- **Co-creation approach:** Our framework promotes and encourages the co-creation of virtual communities by both users and AI agents. Within the virtual community, users have the opportunity to engage in various processes such as planting, as depicted in Figure 2. This collaborative interaction between users and AI agents in the decision-making and co-creation processes contributes to the creation of a more symbiotic community. By leveraging the capabilities of AI agents, users can receive assistance and guidance throughout the physical and virtual community creation processes.
- **User's experience:** One of our keys focuses is to prioritize a better human-centered experience for users. We emphasize the visibility and feasibility of users' feedback within the decision-making and co-creation processes. By providing users with meaningful ways to express their opinions and preferences, we aim to create a system that truly reflects

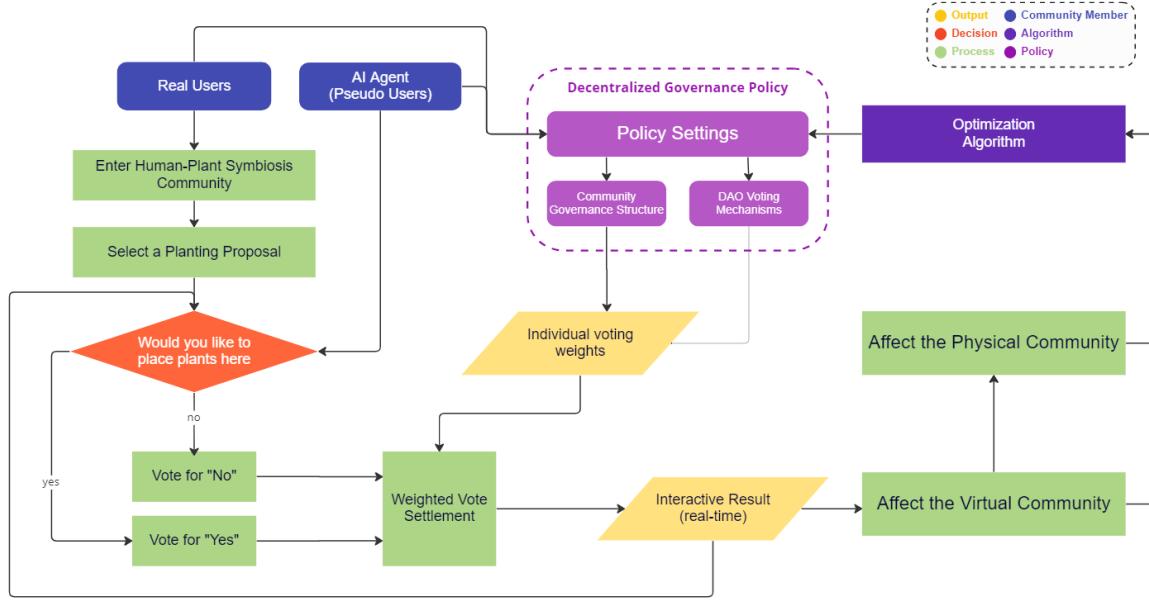


Figure 3: Flowchart of DeGov4VC Framework in Symbiosis Community.

their needs and aspirations. This user-centered approach enhances the overall engagement and satisfaction of participants, facilitating a more effective and inclusive co-design system. By incorporating these design principles, our interactive co-design system empowers users to actively participate in decision-making, co-creation, and community-building processes. Through decentralization, scenario-based exploration, co-creation approaches, and a focus on user experience, we strive to create a framework that enables collaborative and symbiotic interactions between humans, AI agents, and the virtual community.

4 CO-DESIGN SYSTEM

The proposed decentralized governance for the virtual community (DeGov4VC) emphasizes a decentralized approach with virtual reality technology that connects all stakeholders and decisions. This connects stakeholders in a decentralized way, including community residents, community managers, government, and designers. Such a diverse group of stakeholders had different needs and goals in the system design. Therefore, we adopted an interactive co-design approach [5] to learn from policy decisions, decentralization, and community residents and their desired experience of human-plant symbiosis. The co-design process focused on two main issues:

- Identify the shared expectations of multiple stakeholders for a human-plant symbiotic virtual community.
- Make an interactive decision-making process from multiple opinions and get optimal design results.

In addition, to systematically understand the needs of users and managers and design appropriate virtual communities, our research and design path for the DeGov4VC framework is divided into three phases: the concept generation phase, the framework creation phase, and the test and iteration phase. All these three stages

can help various stakeholders better participate in our community framework's design and construction process and interactively carry out design iterations and updates in real-time, as shown in Table 1 and will be discussed in detail in the discussion section.

5 IMPLEMENTATION

As shown in Figure 4, the DeGov4VC implemented a virtual community with AI agents and provided a client as a user interface. For the client, we will use Unity to develop the front end for map visualization and user interactivity, as shown in Figure 1. Specifically, we will use scan-to-BIM to retrieve the digital twin of a physical community and reproduce its model in Unity, which can realize real-time 3D interactive content creation and operation platform [19] and realize digital twinning and interactive community co-creation of multiple scenarios on it. We will mark the plantable area and design several patterns to indicate plant status and also use the GAMA platform [10] to develop the AI agent. Following the BDI [4, 27] paradigm (which allows agents to make decisions), we will develop and generate AI agent instances to communicate with Unity using the MQTT protocol (e.g., to receive the user's input and send the agent's decision).

In the human-machine co-creation process, we use a parameterized decentralized governance policy to regulate the community co-creation process, which determines the community structure and the collective decision-making process. In addition, the outcomes in the virtual community will influence the decision to plant in the physical world. As decisions are made, we will collect feedback data from virtual (online) and physical (offline) communities to form a dataset and use optimization algorithms (e.g., offline reinforcement learning [14, 20]) to iteratively optimize the community's parameterized decentralization policy.

Furthermore, we conduct user studies on whether user creativity, engagement, and stickiness are enhanced by a better online

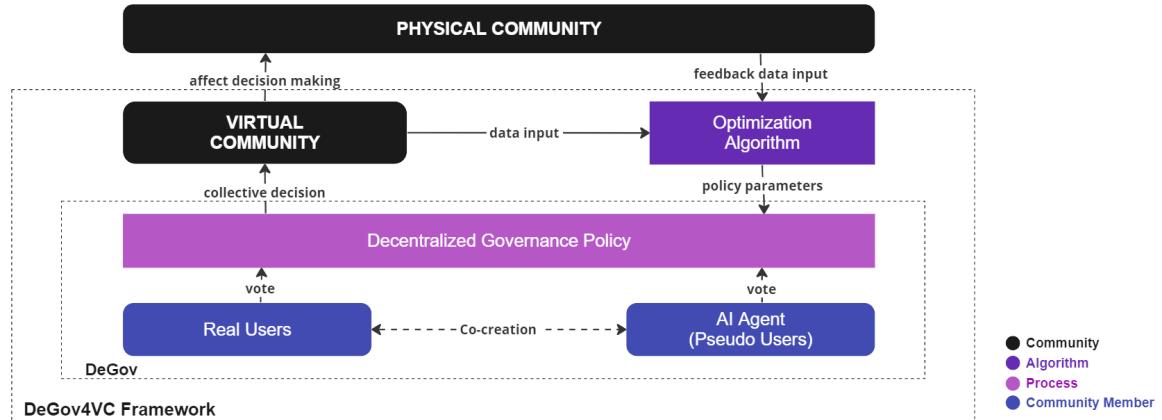


Figure 4: Relationship Diagram of DeGov4VC Framework.

community policy, using a combination of questionnaires, interviews, significance analysis, and semiotic analysis to validate our designs. We use methods such as interviews and usability testing to qualitatively study users' experiences in our community [36]. We conduct quantitative research using methods such as surveys and formal experiments to measure user behavior in a way that can be statistically analyzed. Combining qualitative and quantitative methods [23], we conduct user research to verify that our system really allows users to co-create and generate a better user experience.

6 DISCUSSION

AI is more productive than humans[16], this paper introduces a creative and interactive design framework to improve decentralized governance for the virtual community by combining the collaborative creation and policy decisions of real users and AI agents, as can be seen in Figure 3, which shows the workflow of how different stakeholders will collaborate and interact in our system. The "DeGov4VC" system helps us simulate behavior in virtual reality communities, giving virtual communities more functionality and enabling users to interact more deeply and meaningfully with the VR environment.

Through feedback from co-creation participants, we gained valuable insight into how our system caters to different stakeholders. Different communities have well received our framework. This is consistent with past research highlighting the importance of incorporating new technologies into the creative process [30, 37]. The manager also gave positive feedback on how this system can effectively help to make the decision-making process. Finally, residents responded positively to the interactivity of the framework and their ability to engage with the decision-making process in both online and offline communities. However, some audience members suggested that the framework be more open. For instance, encourage and facilitate open communication among members of this interactive community, foster a sense of inclusively by actively seeking out and welcoming diverse perspectives and backgrounds [9], encourage collaboration and sharing of resources among members of the community, and finally, regularly evaluate and update the system and community based on feedback from users, and be transparent about any changes made. Thus, our framework has the potential

to be further enhanced to meet the needs and expectations of a broader range of stakeholders.

7 CONCLUSION AND FUTURE DEVELOPMENT

This research presents a brand-new design framework for user-engaged co-creation in online and offline communities. DeGov4VC, a co-creation framework, is implemented by our system to create a cooperative symbiosis with nature. The framework investigates a decentralized co-creation framework for community co-creation. Using the example of human-plant symbiosis, this work reveals a more critical perspective on the symbiotic process between broader stakeholders and many community scenarios. Our proposed framework will also assist in developing a new concept of decentralized government and a more desirable network-based co-creative community. As a result, rather than the existing top-down, non-decentralized management style in virtual communities, users will be involved in creating the community (not just in policy decisions related to planting production). Our methodology enhances user experience and participation in virtual communities by including essential stakeholders in the design process.

The effectiveness of a better online community policy in user inventiveness, engagement, and stickiness will be the subject of user studies in future development. We'll conduct surveys, interviews, significance analyses, and semiotic analyses to validate our designs and reveal the participants' feelings about making decisions. Additionally, a semiotic analysis of the visual study of various plant patterns in an online community would be fascinating. Besides, we think that the use of non-fungible tokens in conjunction with user behavior in virtual communities within the metaverse has the potential to serve as a reward and punishment framework. Finally, we would like to investigate further user-user, user-agent, and user-environment interaction techniques in the future.

ACKNOWLEDGMENTS

This research was partially supported by Tongji University - MIT City Science Lab @ Shanghai and the China Academy of Educational Sciences (Project No. JKY16901).

REFERENCES

- [1] Massimiliano Assante, Leonardo Candela, Donatella Castelli, Roberto Cirillo, Gianpaolo Coro, Andrea Dell'Amico, Luca Frosini, Lucio Lelii, Marco Lettere, Francesco Mangiacapra, et al. 2022. Virtual research environments co-creation: The D4Science experience. *Concurrency and Computation: Practice and Experience* (2022), e6925.
- [2] Mela Bettiga, Raul Masu, and Maurizio Teli. 2021. “It's like a GPS community tool”: Tactics to foster Digital Commons through Artifact Ecology. In *Designing Interactive Systems Conference 2021*. 1710–1725.
- [3] Debora Bettiga, Lucio Lamberti, and Giuliano Noci. 2018. Investigating social motivations, opportunity and ability to participate in communities of virtual co-creation. *International journal of consumer studies* 42, 1 (2018), 155–163.
- [4] Mathieu Bourgais, Patrick Taillandier, and Laurent Vercouter. 2020. BEN: An architecture for the behavior of social agents. *Journal of Artificial Societies and Social Simulation* 23, 4 (2020).
- [5] Bill Buxton. 2010. *Sketching user experiences: getting the design right and the right design*. Morgan kaufmann.
- [6] Chian-Hsueung Chao, I-Hsien Ting, Yi-Jun Tseng, Bing-Wen Wang, Shin-Hua Wang, Yu-Qing Wang, and Ming-Chun Chen. 2022. The Study of Decentralized Autonomous Organization (DAO) in Social Network. In *Proceedings of the 9th Multidisciplinary International Social Networks Conference* (Matsuyama, Japan) (MISNC '22). Association for Computing Machinery, New York, NY, USA, 59–65. <https://doi.org/10.1145/3561278.3561293>
- [7] Simran Chopra, Rachel E Clarke, Adrian K Clear, Sara Heitlinger, Ozge Dilaver, and Christina Vasiliou. 2022. Negotiating sustainable futures in communities through participatory speculative design and experiments in living. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*. 1–17.
- [8] Rachel Clarke, Jo Briggs, Ann Light, and Pete Wright. 2016. Situated encounters with socially engaged art in community-based design. In *Proceedings of the 2016 ACM conference on designing interactive systems*. 521–532.
- [9] Andy Dow, Kyle Montague, Shauna Concannon, and John Vines. 2022. Scaffolding Young People's Participation in Public Service Evaluation through Designing a Digital Feedback Process. In *Designing Interactive Systems Conference*. 319–334.
- [10] Alexis Drogoul, Edouard Amouroux, Philippe Caillou, Benoit Gaudou, Arnaud Grignard, Nicolas Marilleau, Patrick Taillandier, Maroussia Vassasseur, Duc-An Vo, and Jean-Daniel Zucker. 2013. GAMA: a spatially explicit, multi-level, agent-based modeling and simulation platform. In *Advances on Practical Applications of Agents and Multi-Agent Systems: 11th International Conference, PAAMS 2013, Salamanca, Spain, May 22–24, 2013. Proceedings 11*. Springer, 271–274.
- [11] Youssef El Faqir, Javier Arroyo, and Samer Hassan. 2020. An Overview of Decentralized Autonomous Organizations on the Blockchain. In *Proceedings of the 16th International Symposium on Open Collaboration (Virtual conference, Spain) (OpenSym '20)*. Association for Computing Machinery, New York, NY, USA, Article 11, 8 pages. <https://doi.org/10.1145/3412569.3412579>
- [12] Chris Elsden, Arthi Manohar, Jo Briggs, Mike Harding, Chris Speed, and John Vines. 2018. Making Sense of Blockchain Applications: A Typology for HCI. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) (CHI '18). Association for Computing Machinery, New York, NY, USA, 1–14. <https://doi.org/10.1145/3173574.3174032>
- [13] Jan Fell, Travis Greene, Jyun-Cheng Wang, and Pei-Yi Kuo. 2020. Beyond human-centered design: Proposing a biocentric view on design research involving vegetal subjects. In *Companion Publication of the 2020 ACM Designing Interactive Systems Conference*. 209–214.
- [14] Justin Fu, Aviral Kumar, Ofir Nachum, George Tucker, and Sergey Levine. 2020. D4rl: Datasets for deep data-driven reinforcement learning. *arXiv preprint arXiv:2004.07219* (2020).
- [15] Ze Gao and Lin Lin. 2021. The intelligent integration of interactive installation art based on artificial intelligence and wireless network communication. *Wireless Communications and Mobile Computing* 2021 (2021), 1–12.
- [16] Ze Gao, Sihuang Man, and Anqi Wang. 2022. AI Art and Design Creation Industry: The Transformation from Individual Production to Human-Machine Symbiosis. In *2022 World Automation Congress (WAC)*. IEEE, 52–56.
- [17] Ze Gao, Anqi Wang, Pan Hui, and Tristan Braud. 2022. Bridging Curatorial Intent and Visiting Experience: Using AR Guidance as a Storytelling Tool. In *The 18th ACM SIGGRAPH International Conference on Virtual-Reality Continuum and its Applications in Industry*. 1–10.
- [18] Hyekyung Imottesjo and Jaan-Henrik Kain. 2022. The Urban CoCreation Lab—An Integrated Platform for Remote and Simultaneous Collaborative Urban Planning and Design through Web-Based Desktop 3D Modeling, Head-Mounted Virtual Reality and Mobile Augmented Reality: Prototyping a Minimum Viable Product and Developing Specifications for a Minimum Marketable Product. *Applied Sciences* 12, 2 (2022). <https://doi.org/10.3390/app12020797>
- [19] Arthur Juliani, Vincent-Pierre Berges, Ervin Teng, Andrew Cohen, Jonathan Harper, Chris Elion, Chris Goy, Yuan Gao, Hunter Henry, Marwan Mattar, et al. 2018. Unity: A general platform for intelligent agents. *arXiv preprint arXiv:1809.02627* (2018).
- [20] Sergey Levine, Aviral Kumar, George Tucker, and Justin Fu. 2020. Offline reinforcement learning: Tutorial, review, and perspectives on open problems. *arXiv preprint arXiv:2005.01643* (2020).
- [21] Szu-Yu Liu, Shaowen Bardzell, and Jeffrey Bardzell. 2019. Symbiotic encounters: HCI and sustainable agriculture. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–13.
- [22] Sihuang Man and Ze Gao. 2022. Digital immersive interactive experience design of museum cultural heritage based on virtual reality technology. *Journal of Electronic Imaging* 32, 1 (2022), 011208.
- [23] Clodagh McLoughlin, Kunal D Patel, Tom O'Callaghan, and Scott Reeves. 2018. The use of virtual communities of practice to improve interprofessional collaboration and education: findings from an integrated review. *Journal of interprofessional care* 32, 2 (2018), 136–142.
- [24] Christoph Mueller-Bloch, Jonas Valbjørn Andersen, Jason Spasovski, and Jungpil Hahn. 2022. Understanding decentralization of decision-making power in proof-of-stake blockchains: an agent-based simulation approach. *European Journal of Information Systems* (2022), 1–20.
- [25] Ajit G Pillai, Naseem Ahmadpour, Soojeong Yoo, A Baki Kocaballi, Sonja Pedell, Vinoth Pandian Sermuga Pandian, and Sarah Sulteri. 2020. Communicate, critique and co-create (CCC) future technologies through design fictions in VR environment. In *Companion Publication of the 2020 ACM Designing Interactive Systems Conference*. 413–416.
- [26] Steven F Railsback, Steven L Lytinen, and Stephen K Jackson. 2006. Agent-based simulation platforms: Review and development recommendations. *Simulation* 82, 9 (2006), 609–623.
- [27] Anand S Rao, Michael P Georgeff, et al. 1995. BDI agents: from theory to practice.. In *Icmas*, Vol. 95. 312–319.
- [28] S. Ray, S. S. Kim, and J. G. Morris. 2014. The Central Role of Engagement in Online Communities. *Information Systems Research* 25, 3 (2014), 528–546.
- [29] Nuria Rodríguez-López. 2021. Understanding value co-creation in virtual communities: The key role of complementarities and trade-offs. *Information & Management* 58, 5 (2021), 103487.
- [30] Joshua Paolo Seguin, Delvin Varghese, Misita Anwar, Tom Bartindale, and Patrick Olivier. 2022. Co-designing Digital Platforms for Volunteer-led Migrant Community Welfare Support. In *Designing Interactive Systems Conference*. 247–262.
- [31] Andrea Tocchetti, Lorenzo Corti, Marco Brambilla, and Diletta Di Marco. 2021. A Web-Based Co-Creation and User Engagement Method and Platform. In *Web Engineering: 21st International Conference, ICWE 2021, Biarritz, France, May 18–21, 2021, Proceedings*. Springer, 496–501.
- [32] Anna Vasilchenko, Jie Li, Bektrur Ryskeldiev, Sayan Sarcar, Yoichi Ochiai, Kai Kunze, and Julian Radu. 2020. Collaborative Learning Co-Creation in XR. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) (CHI EA '20). Association for Computing Machinery, New York, NY, USA, 1–4. <https://doi.org/10.1145/3334480.3381056>
- [33] Aditya Vishwanath, Naveena Karusala, Marisol Wong-Villacres, and Neha Kumar. 2019. Engaging lived and virtual realities. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–15.
- [34] Sim Wai, Cheah Waishiang, Muhammad Asyraf Khairuddin, Yanti Bujang, Rahmat Hidayat, and Celine Haren Paschal. 2021. Autonomous Agents in 3D Crowd Simulation Through BDI Architecture. *JOIV: International Journal on Informatics Visualization* 5 (03 2021), 1. <https://doi.org/10.30630/joiv.5.1.371>
- [35] Anqi Wang, Ze Gao, Lih Hang Lee, Tristan Braud, and Pan Hui. 2022. Decentralized, not Dehumanized in the Metaverse: Bringing Utility to NFTs through Multimodal Interaction. In *Proceedings of the 2022 International Conference on Multimodal Interaction*. 662–667.
- [36] Tom D Wilson. 1981. On user studies and information needs. *Journal of documentation* 37, 1 (1981), 3–15.
- [37] Pinar Yelmi and Tulu Bayar. 2020. Designing an Interactive Non-Linear Documentary Contributed by Public Participation: Suburbs of Istanbul. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference* (Eindhoven, Netherlands) (DIS '20). Association for Computing Machinery, New York, NY, USA, 747–755. <https://doi.org/10.1145/3357236.3395504>
- [38] Stefano Za, Jessie Pallud, Rocco Agrifoglio, and Concetta Metallo. 2020. Value co-creation in online communities: A preliminary literature analysis. In *Exploring Digital Ecosystems: Organizational and Human Challenges*. Springer, 33–46.