Designing living artefacts: Opportunities and challenges for biodesign

Kim, Raphael; Zhou, J.; Groutars, E.G.; Karana, E.

DOI
0.21606/drs.2022.942

Publication date
2022

Document Version
Final published version

Published in
Proceedings DRS 2022

Jun 25th, 9:00 AM

Designing living artefacts: Opportunities and challenges for biodesign

Raphael Kim
Delft University of Technology, The Netherlands

Jiwei Zhou
Delft University of Technology, The Netherlands

Eduard Georges Groutars
Avans University of Applied Sciences, The Netherlands

Elvin Karana
Delft University of Technology, The Netherlands

Citation

Kim, R., Zhou, J., Groutars, E.G., and Karana, E. (2022) Designing living artefacts: Opportunities and challenges for biodesign, in Lockton, D., Lenzi, S., Hekkert, P., Oak, A., Sádaba, J., Lloyd, P. (eds.), *DRS2022: Bilbao*, 27 June - 3 July, Bilbao, Spain. https://doi.org/10.21606/drs.2022.942

DRS 2022
Bilbao 25th June — 3rd July

Designing living artefacts: Opportunities and challenges for biodesign

Raphael Kim[a]*, Jiwei Zhou[a], Eduard Georges Groutars[a,b], Elvin Karana[a]

[a]Delft University of Technology, The Netherlands
[b]Avans University of Applied Sciences, The Netherlands

*corresponding e-mail: r.kim@tudelft.nl

doi.org/10.21606/drs.2022.942

Abstract: Biodesign is an emerging form of design practice integrating biological materials and processes, and there is a growing interest in the field for structured conversations to generate insights on how it can be best taught, researched, and disseminated. In our conversations, we began exploring biodesign under the framework of Living Artefacts, in which livingness is prolonged to the use time of artefacts, and understood as a biological, ecological, and experiential phenomenon. Two researchers investigating Living Artefacts, through their short show-and-tell presentations, initiated threads of moderated open discussions. Using the Living Artefacts framework as a departure point, we collectively explored opportunities and challenges in biodesign, and possible ways in which they could be addressed.

Keywords: biodesign, living artefacts, living aesthetics, habitabilities, microorganisms

1. Introduction

Bio-design is an emerging form of design practice that uses and integrates biological materials and processes, often through a variety of technological implementation (e.g., Camere & Karana, 2018; Myers 2012; Collet, 2013; Ginsberg et al., 2017; Kim et al., 2018; Kim et al., 2022; Zhou et al., 2021; Groutars & Risseeuw et al., 2022). As a field that is increasingly broadening with diversity of materials, organisms, processes, and stakeholders, there is a growing interest in fostering appropriately contextualized discussions in biodesign, in order to progress the field in a constructive and meaningful way. Such discussions can revolve around a particular approach to biodesign, focusing on how it could be best implemented, and identifying a set of competences that would be desirable in undertaking the approach. In our conversations, we explore biodesign with a special focus on Living Artefacts, in which livingness is prolonged to the use time of artefacts. Karana et al. (2020) have recently introduced a biodesign framework for the design of Living Artefacts where livingness is understood as a biological, ecological, and experiential phenomenon (Karana et al., 2020).

The framework proposes three principles for designing for livingness: Living Aesthetics, Mutualistic Care, and Habitabilities. Taking these principles as a departure point in our conversations, we heard how some of the current biodesign practitioners have addressed the framework in their works, intersected with an open (moderated) group discussion on how it could be addressed in the future. If the three principles of living artefacts are fundamental to biodesign practice, how should biodesigners tackle each of them? The overall aims of the conversation, therefore, has been two-fold: 1) To address the opportunities of Living Artefacts, by exploring its scope and latest related works to the wider design research community, and 2) To address the challenges, through critical discourse on best practice, and mapping out desirable competencies for the future biodesigner. By gaining a better understanding of the implications of designing living artefacts, it would contribute to the existing design research community, on at least three fronts. Whilst we did not aim for the conversation to cover all domains of biodesign, we viewed it as a valuable starting point for further discussions for the road ahead. In terms of biodesign pedagogy, the conversation could be translated into the needs and learning goals of prospective bio-design students, which in turn would help towards formulation and management of biodesign educational programmes. In terms of epistemology, researchers could be better positioned to evaluate and discuss bio-designers' works in critical and meaningful ways. And in terms of dissemination, future designers would be able to better position their works to the wider public and to foster constructive dialogue with them.

2. Session structure

The Conversations session was delivered in person at the conference venue. The session was also streamed online. Below describes the general format of the session that was held: Brief opening remarks from the lead convener (Kim), who introduced the two speakers: Jiwei Zhou and Eduard Groutars. Each speaker gave a brief "show and tell" format presentations, titled "Habitabilities of Living Artefacts: A Taxonomy of Digital Tools for Biodesign" (Zhou), and "On the Living Aesthetics of Iridescent Flavobacteria" (Groutars). Through the talks, each speaker addressed 1) how their work relates to living artefacts, and 2) reflected on lessons they have learnt during their work. The idea was to use the talk as springboards for the audience and participants of the session to react and discuss. Between each talk, the lead convener opened the conversation to the floor, giving time for the audience/participants, who were invited to react and comment on the previous talk. The lead convener moderated the session to ensure that a range of different views could be heard. Following the two sets of talks and discussions, the lead convener thanked the audience and closed the session with a short summary. To contextualize the conversations further, the speakers had been carefully chosen and their talks curated, to include works that implicate human interactions with microorganisms (Kim et al., 2021), an example of living material and interface (Merritt et al., 2020) increasingly implicated in interaction design (e.g., Kim et al., 2019; Pataranutaporn et al., 2020; Zhou et al., 2021; Groutars & Risseeuw et al., 2022). In the

following sections, we summarize the contents of the two talks, followed by a brief summary of follow up discussions.

3. "Habitabilities of Living Artefacts: A Taxonomy of Digital Tools for Biodesign" by Jiwei Zhou

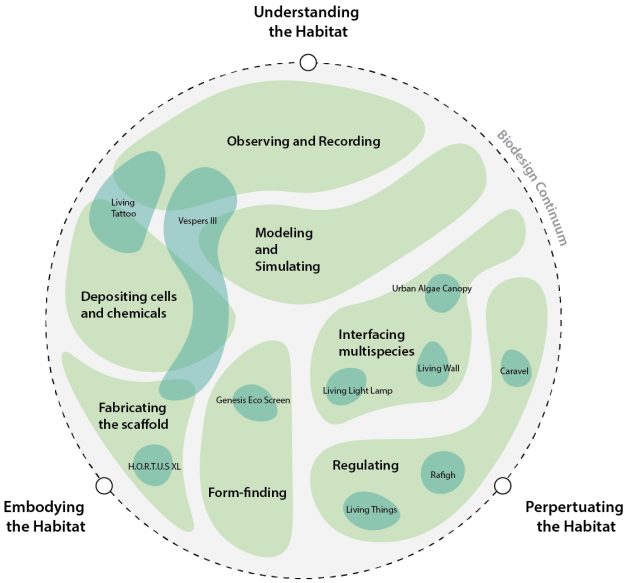

Figure 1. Taxonomy of digital tools for understanding and designing for habitabilities in biodesign (Zhou et al., 2022).

In recent years, design and HCI researchers have shown interest in biological materials to achieve novel functionalities and interaction possibilities in everyday artefacts, in which computer input and output can be complemented or ultimately substituted by living organisms (Cheok et al., 2008; Gough et al., 2021; Hamidi & Baljko, 2014; Holstius et al., 2004; Merritt et al., 2020; Parkes & Dickie, 2013; Pataranutaporn et al., 2020; Pataranutaporn et al., 2018; Yao et al., 2015). In parallel, informed by an epistemologically pluralist commitment, scholars have introduced a rich vocabulary for decentering humans and carefully involving non-human species (e.g., animals, plants, and other living things), which have been adopted in HCI research and design (see, for example, Aspling et al., 2016; Liu et al., 2018; Liu et al., 2019; Smith et al., 2017). The above mentioned works depict a continuum of relationships between biological systems, computers, and humans that spans from single, one-way functional relations to a multispecies web of symbiotic relationships. In line with this continuum, we believe that in the design of living artefacts (Karana et al., 2020), it is crucial to empower both designers and users to perpetuate the livingness of the organism through a careful crafting of habitabilities that attends to the mutual well-being of both humans and non-humans. And, we believe digital tools can play a key role in that.

In biodesign, biological systems have often been coupled with advanced digital tools to assist practitioners in the biofabrication of artefacts (Camere & Karana, 2017). But digital tools can

also foster communication, cooperation, and affective forms of interaction between living organisms and humans. To this end, the concept of habitability is a key element in designing living artefacts, emphasizing the need for a purposeful exploration of the abilities of both humans and non-humans to not only create a livable habitat at design time, but also to perpetuate it to the use time of artefacts (Karana et al., 2020, p. 48). Taking habitabilities as a lens in our biodesign research, and informed by the existing roles of digital technologies in biodesign (Camere & Karana, 2017), we have recently introduced a taxonomy that articulates the roles digital tools can play in crafting habitabilities in the design of living artefacts (Figure 1). The taxonomy is grounded in a systematic analysis of ten cases of living artefacts from art, design, and HCI, and it identifies three roles for digital tools: understanding, embodying, and perpetuating the habitat.

The presented taxonomy will guide design and HCI communities in exploring new ways of understanding, embodying, and perpetuating the habitat for living organisms, as well as foreseeing challenges that otherwise might be overlooked. To sum up, the taxonomy aims at 1) providing a conceptual framework to support the understanding of, and designing for, habitabilities through digital tools, 2) presenting case-specific practical knowledge to support new biodesign endeavours, e.g., design for perpetuation, and 3) inspiring the appropriation of the existing digital tools or their advancement as well as the development of novel digital tools to support more complicated scenarios in design and HCI (e.g., tools for empathetic interfaces between humans and living artefacts), and helping biodesigners and researchers to position the role of these tools in their specific projects.

In the talk, two emerging directions from the taxonomy that need to take center stage in the design of such systems were emphasized, and the implications of the taxonomy for future biodesign and HCI research were highlighted.

Design for Perpetuation

Science and engineering studies offer solutions for self-sustaining habitats in the context of Engineered Living Materials (ELM) (e.g., González et al., 2020; Liu & Xu, 2020; Elias & Banin, 2012). Likewise, for living artefacts we see potential in incorporating digital technologies particularly to support self-sustaining habitats (see in the taxonomy, e.g., *Caravel* and *The Living Things*). On the other hand, from a social perspective, the (symbiotic) relation between humans and non-humans could be considered in creating a livable habitat for living organisms throughout their life. Future design methods should accommodate the design of such living artefacts, anticipate possible consequences, and consider the contextual significance of the symbiotic relation. Designing for perpetuation then, requires designers to draw special attention, from the very beginning of the design process, to how habitability is biologically configured at design time as well as socially maintained at use time. Envisioning scenarios of care will be central to designing for perpetuation in the design of living artefacts.

Design for Multispecies Cohabitation

When designers hand over the living artefact to users, the design of the living artefact is not finished: it is extended in use. It remains open to change, and over time will adapt in use, in a dynamic and unexpected way (see, for example *Urban Algae Canopy* by ecoLogicStudio). Communication between the human and non-human entities sharing the same habitat usually results in a highly dynamic interplay that cannot be fully anticipated. Similar to future algorithmic practices (Giaccardi & Redström, 2020), this will require a biodesign practice that discerns and integrates different capabilities (human and non-human) into appropriate co-performances (Kuijer & Giaccardi, 2018). Herein, we foresee the potential of digital tools in fostering co-performance in support of practices which help maintain the wellbeing of both humans and non-humans in everyday life, i.e., cohabitation.

4. "On the Living Aesthetics of Iridescent Flavobacteria" by Eduard Groutars

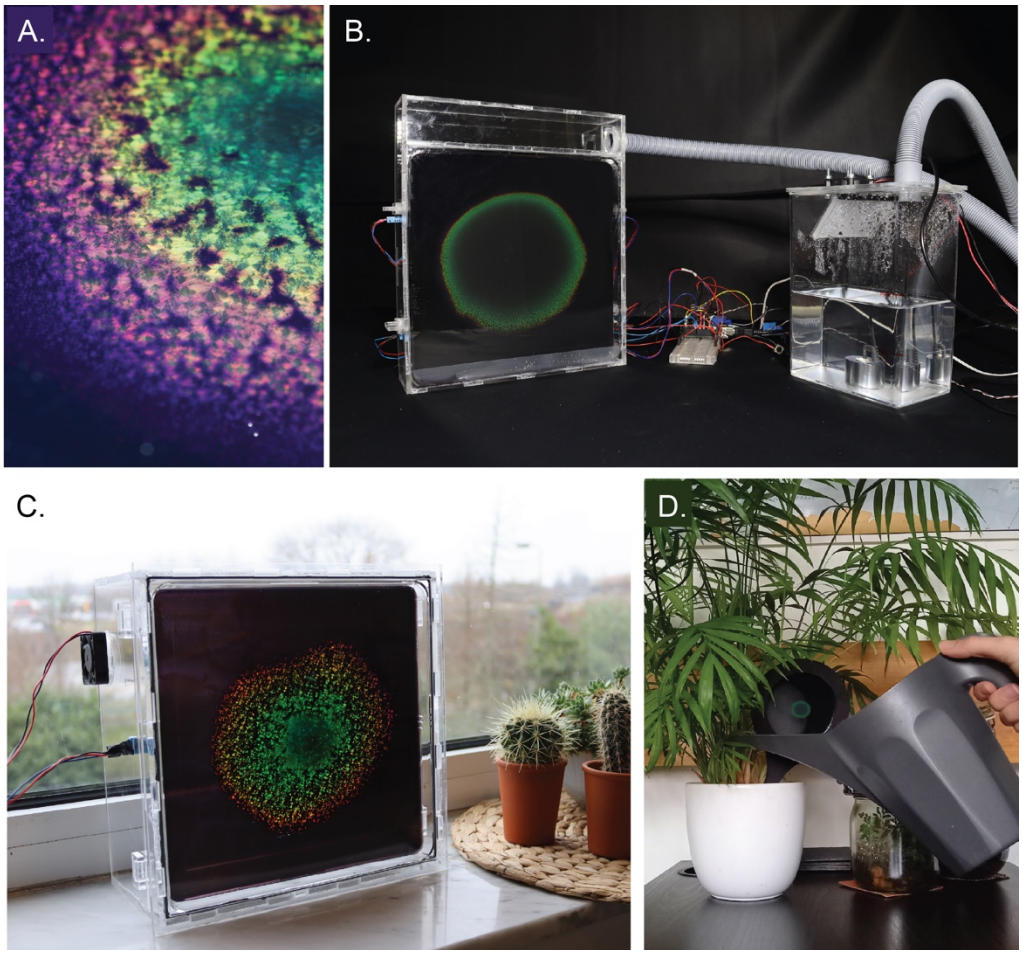

Figure 2. A: Macro photograph of Flavobacteria's structural color. B: Flavorium. C: Living Monitor concept. D: Living Label concept. Adapted from Groutars & Risseeuw et al., 2022.

Flavobacteria are naturally occurring marine bacteria with the ability to form highly organized optical structures in their colonies (Kientz et al., 2016). When illuminated by white light, these structures result in vivid iridescent colorations, visible to the naked human eye (Figure 2A). Aside from being of interest for the development of bio-based colorants, researchers have also explored the temporal qualities inherent to the organisms' livingness. Flavobacteria's colors will appear, change, and eventually fade, depending on their life-cycle as well the influence of various environmental factors. Here, efforts have been made to quantify this changing appearance in relation to the livingness of the medium, as well as methods of communicating their living aesthetics to the human viewer (Groutars & Risseeuw et al., 2022).

Working with these living organisms requires the use of a microbiological laboratory and relevant protocols. Here designers are faced with various challenges and limitations, including safety regulations, maintaining sterility, and also providing the required *habitabilities* for the living organism to thrive. The principle of habitabilities urges designers to think about nutrients, air flow, humidity, and other factors required to perpetuate the livingness of the medium. In order to address this, Flavorium was developed (Figure 2B). A custom made habitat that enables large scale growth of Flavobacteria allows designers to tune the habitabilities. In addition, the living organisms response can be observed whilst maintaining sterility, enabling 'out of the lab' applications. Here we envision that the development of such a custom made habitat can be a common first step in any biodesign process where livingness is considered.

With the ability to tune and observe Flavobacteria's behaviour came the development of a *Living Monitor* (Figure 2C). Here abstract digital data is coupled to the *Living Aesthetics* of Flavobacteria by means of Flavorium. Such data, for example relating to a person's health and lifestyle, can be translated to the humidity levels inside Flavorium. This will in turn cause Flavobacteria to expand either rapidly or slowly, displaying a specific texture and varying degrees of brightness and color. In this manner, the way in which Flavobacteria's appearance changes over time and how this is interpreted by the human viewer will result in specific Living Aesthetics that tell a story about the person's lifestyle.

Exploring the third principle of the living artefacts framework, *Mutualistics Care*, is the concept of a *Living Label*. Here the Flavobacteria inhabiting the Living Label are in direct contact with the humidity of the soil from which a houseplant resides. Whether the soil is too dry, too wet, or just right, the livingness of the plant will be reflected in the growth and color of the Flavobacteria, which essentially acts as a soil humidity sensor. As such, Flavobacteria's Living Aesthetics synergizes with the well-being of the house plant, which in turn encourages humans to provide appropriate care for both the plant and the bacteria.

One of the areas currently being considered for further work is the correlation between living aesthetics of flavobacteria, and their ability to generate human empathy, with the aim of gaining a better understanding of how the microorganism can be designed to foster a sustainable relationship between humans, microbes, and technology.

5. Summary

The Conversation was well attended by participants, with most attendees coming from art and design backgrounds, and only a couple had biodesign research and/or teaching experiences. The two talks were well-received, and harvested interesting discussions on a number of topics in relation to living artefacts and biodesign. One thread of such discussions revolved around how much of existing biodesign research and practices have been somewhat 'restricted' to the lab environment, and may offer a richer learning and research experience outside of it. Ethical aspects of practicing biodesign was also discussed, with some suggesting that a distinct ethical framework (in extension to existing ones) was necessary for those working with non-sentient microorganisms such as mycelium and bacteria. Furthermore, the conveners also felt that ethical debates in biodesign could have moved beyond those concerning visual aesthetics of living artefacts (e.g., transparent plastic containments), and towards those that concern meeting final design goals (e.g., addressing sustainability).

A future iteration of this conversation could begin the session with a general overview of biodesign, before opening up to a more detailed/technical discussion on living artefacts. In the Conversations session, we were surprised to learn that the majority of the audience was not familiar with biodesign, which may have positioned 'living artefacts' a challenging topic for group discussion with sufficient depth and nuance. Future Conversations, therefore, could ensure that the audiences are selected for their prior experience and knowledge in biodesign, and/or ensure sufficient time is allocated towards overviewing the biodesign field, before living artefacts concept is introduced and discussed. Overall, the conveners believe that there is a scope to further investigate some of the points raised within the discussion over a broader audience of contributors and across different territories.

6. References

Aspling, F., Wang, J., & Juhlin, O. (2016). Plant-computer interaction, beauty and dissemination. In Proceedings of the Third International Conference on Animal-Computer Interaction (pp. 1-10).

Camere, S., & Karana, E. (2017). Growing materials for product design. In Alive. Active. Adaptive: Proceedings of International Conference on Experiential Knowledge and Emerging Materials (EKSIG 2017) (pp. 101-115).

Camere, S., & Karana, E. (2018). Fabricating materials from living organisms: An emerging design practice. Journal of Cleaner Production, 186, 570-584. https://doi.org/10.1016/j.jclepro.2018.03.081

Cheok, A. D., Kok, R. T., Tan, C., Newton Fernando, O. N., Merritt, T., & Sen, J. Y. P. (2008). Empathetic living media. In Proceedings of the 7th ACM conference on Designing interactive systems (pp. 465-473).

Collet, C. (2013). This is alive. Retrieved 05/02/2022 from http://thisisalive.com/

Elias, S., & Banin, E. (2012). Multi-species biofilms: living with friendly neighbors. FEMS microbiology reviews, 36(5), 990-1004.

Giaccardi, E., & Redström, J. (2020). Technology and more-than-human design. Design Issues, 36(4), 33-44.

Ginsberg, A. D., Calvert, J., Schyfter, P., Elfick, A., & Endy, D. (2017). Synthetic aesthetics: investigating synthetic biology's designs on nature. MIT press.

González, L. M., Mukhitov, N., & Voigt, C. A. (2020). Resilient living materials built by printing bacterial spores. Nature chemical biology, 16(2), 126-133.

Gough, P., Yoo, S., Tomitsch, M., & Ahmadpour, N. (2021). Applying Bioaffordances through an Inquiry-Based Model: a literature review of interactive biodesign. International Journal of Human–Computer Interaction, 37(17), 1583-1597.

Groutars, E.G., Risseeuw, C.C., Ingham, C.J., Hamidjaja, R., Elkhuizen, W.S., Pont, S.C., & Karana, E. (2022). Flavorium: an exploration of Flavobacteria's living aesthetics for living color interfaces. In Proceedings of the 2022 CHI conference on human factors in computing systems (pp. 1-19). https://doi.org/10.1145/3491102.3517713

Hamidi, F., & Baljko, M. (2014). Rafigh: a living media interface for speech intervention. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 1817-1820).

Holstius, D., Kembel, J., Hurst, A., Wan, P. H., & Forlizzi, J. (2004). Infotropism: living and robotic plants as interactive displays. In Proceedings of the 5th conference on Designing interactive systems: processes, practices, methods, and techniques (pp. 215-221).

Karana, E., Barati, B., & Giaccardi, E. (2020). Living artefacts: Conceptualizing livingness as a material quality in everyday artefacts. International Journal of Design, 14(3), 37-53. http://www.ijdesign.org/index.php/IJDesign/article/view/3957/923

Kim, R., Thomas, S., van Dierendonck, R., & Poslad, S. (2018). A new mould rush: designing for a slow bio-digital game driven by living micro-organisms. In Proceedings of the 13th International Conference on the Foundations of Digital Games (pp. 1-9). https://doi.org/10.1145/3235765.3235798

Kim, R., & Poslad, S. (2019). Growable, invisible, connected toys: twitching towards ubiquitous bacterial computing. In Proceedings of the Halfway to the Future Symposium 2019 (pp. 1-9). https://doi.org/10.1145/3363384.3363387

Kim, R., Pataranutaporn, P., Forman, J., Lee, S. A., Riedel-Kruse, I. H., Alistar, M., Lazaro Vasquez, E.S., Vega, K., van Dierendonck, R., Gome, G., Zuckerman, O., Vujic, A., Kong, D.S., Maes, P., Ishii, H., Sra, M., & Poslad, S. (2021). Microbe-HCI: Introduction and Directions for Growth. In Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems (pp. 1-4). https://doi.org/10.1145/3411763.3450408

Kim, R., Linehan, C., & Pschetz, L. (2022). Navigating Imaginaries of DNA-Based Digital Data Storage. In CHI Conference on Human Factors in Computing Systems (pp. 1-15). https://doi.org/10.1145/3491102.3501911

Kientz, B., Luke, S., Vukusic, P., Péteri, R., Beaudry, C., Renault, T., Simon, D., Mignot, T., & Rosenfeld, E. (2016). A unique self-organization of bacterial sub-communities creates iridescence in Cellulophaga lytica colony biofilms. Scientific reports, 6(1), 1-11. https://doi.org/10.1038/srep19906

Kuijer, L., & Giaccardi, E. (2018). Co-performance: Conceptualizing the role of artificial agency in the design of everyday life. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (pp. 1-13).

Liu, J., Byrne, D., & Devendorf, L. (2018). Design for collaborative survival: An inquiry into human-fungi relationships. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (pp. 1-13).

Liu, S. Y., Bardzell, S., & Bardzell, J. (2019). Symbiotic encounters: HCI and sustainable agriculture. In Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (pp. 1-13).

Liu, S., & Xu, W. (2020). Engineered living materials-based sensing and actuation. Frontiers in Sensors, 1, 586300.

Merritt, T., Hamidi, F., Alistar, M., & DeMenezes, M. (2020). Living media interfaces: a multi-perspective analysis of biological materials for interaction. Digital Creativity, 31(1), 1-21.

Myers, W. (2012). Biodesign. Nature, science, creativity. High Holborn, UK: Thames & Hudson.

Parkes, A., & Dickie, C. (2013). A biological imperative for interaction design. In CHI'13 Extended Abstracts on Human Factors in Computing Systems (pp. 2209-2218).

Pataranutaporn, P., Ingalls, T., & Finn, E. (2018). Biological HCI: towards integrative interfaces between people, computer, and biological materials. In Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems (pp. 1-6).

Pataranutaporn, P., Vujic, A., Kong, D. S., Maes, P., & Sra, M. (2020). Living bits: Opportunities and challenges for integrating living microorganisms in human-computer interaction. In Proceedings of the Augmented Humans International Conference (pp. 1-12).

Smith, N., Bardzell, S., & Bardzell, J. (2017). Designing for cohabitation: Naturecultures, hybrids, and decentering the human in design. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (pp. 1714-1725).

Yao, L., Ou, J., Cheng, C. Y., Steiner, H., Wang, W., Wang, G., & Ishii, H. (2015). BioLogic: natto cells as nanoactuators for shape changing interfaces. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (pp. 1-10).

Zhou, J., Barati, B., Wu, J., Scherer, D., & Karana, E. (2021). Digital biofabrication to realize the potentials of plant roots for product design. Bio-Design and Manufacturing, 4(1), 111-122. https://doi.org/10.1007/s42242-020-00088-2

Zhou, J., Barati, B., Giaccardi, E., & Karana, E. (2022). Habitabilities of living artefacts: A taxonomy of digital tools for biodesign. International Journal of Design, 16(2), 57-73. https://doi.org/10.57698/v16i2.05

About the Authors:

Raphael Kim is a postdoctoral researcher at Materials Experience Lab, TU Delft. He is interested in designing playful human-microbe interactions, and fostering critical dialogues on the sociocultural implications of biotechnology in interaction design.

Jiwei Zhou is a PhD candidate at Materials Experience Lab (Industrial Design Engineering, TU Delft). Her research and design practices have been focusing on novel materials (e.g., living plant roots) experiences. Currently she's working on "habitabilities of living artefacts".

Eduard Groutars combines microbiology and interaction design in his research. A fascination with the natural world and its diversity has led him to collaborate with multiple species of microorganisms, investigating the potential roles they can play in our daily lives.

Elvin Karana explores and navigates the productive shifts between materials science and design to radically change and enhance the relationship people have with materials of artefacts. She is the founder of Materials Experience Lab.