Bio-Cyber-Physical ‘Planetoids’ for Repopulating Residual Spaces

Pierre Oskam [1,2,3], **Henriette Bier** [2,4], **& Hamed Alavi** [5]

[1] *University of Aveiro (Portugal)*
[2] *TU Delft (the Netherlands)*
[3] *University of Porto (Portugal)*
[4] *Politecnico Milano (Italy)*
[5] *University of Fribourg (Switzerland)*

Abstract

Minimal interventions that provide various microclimates can stimulate both biodiversity and social accessibility of leftover spaces. New habitats are often developed for different animal and plant species based on studies of the microclimates typical of such residual spaces. By introducing interventions of 0.5-1.0 m diameter ‘planetoids’ placed at various locations, existing and new life is supported. The ‘planetoid’ described in this paper is prototyped by means of Design-to-Robotic-Production and -Operation (D2RP&O). This implies that it is not only produced by robotic means, but that it contains sensor-actuator mechanisms that allow humans to interact with them by establishing a bio-cyber-physical feedback loop.

Keywords

Bio-cyber-Physical Systems, Computational Design, Robotic Production and Operation, Artificial Intelligence, Residual Space, Minimal Intervention

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Context

In Europe, large swathes of built space have been abandoned. The abandonment is related to rapid programmatic changes due to deindustrialization, population ageing, migration, political and economic shifts, cultural reframing or ineffective planning (Accordino and Johnson, 2000; Haase, et al., 2016). As a consequence, a variety of spatial forms emerge, such as abandoned villages and industrial buildings, neglected agricultural land, polluted and exhausted mines, et cetera. The prevailing aggressive capitalist way of dealing with space leads to increased social polarization and a global decline in biodiversity which in turn fuels the increase in abandoned, unused places. A cost-efficient strategy is needed that can enrich those places for both human and non-human use.

The need to find low-cost solutions to improve the social and ecological value of residual places that do not involve large investments is addressed in this project by exploiting available on-site assets and digital technologies. Residual places may contain invisible but valuable assets such as unique animal and plant species (e.g. Laurie, 1979). Residual places provide opportunities for wildlife and spontaneous succession within the urban fabric (Kawata, 2014) by offering refuge for species displaced by intensive agriculture (Harrison & Davies, 2002; Kowarik, 2013; Schwarz, 1980). Residual places can introduce new opportunities for material and social interaction. The absence of rules brings about a sense of freedom, creating a place of possibility while hosting various forms of interaction, such as artistic creation, adventurous play, and exploration (Edensor, 2005). The 'emptiness' of those places offers an alternative to the often overcrowded, predictable spaces of the city, providing scope to question the over-regulated way that contemporary urban space is formed (Edensor, 2005). The challenge is to find solutions that improve the socio-ecological value of such places without requiring large investments.

FIGURE 1 *Minimal interventions in leftover spaces have the potential to stimulate biodiversity and social accessibility.*

Site Interventions

A possible strategy to enhance residual spaces is to apply 'minimal interventions' (Lassus, 1998) that could stimulate both biodiversity and social accessibility. Such 'minimal interventions' trigger transformation in the spatial experience. The interventions resemble miniature planets, as they are roughly spherical and have at least partially differentiated interiors (Schmidt et al., 2007). The 'planetoids' take the form of 0.5-1.0 m diameter artefacts (Fig. 1) large enough to relate to the architecture of the site and small enough to be easily handled by humans. Their porosity contributes to the development of ecosystems by hosting a wide number of species. They support the life that already exists at the location, but they also attract new life. They provide opportunities for unforeseen interactions and, therefore, for the 'unintended' to happen (Oskam and Mota, 2020).

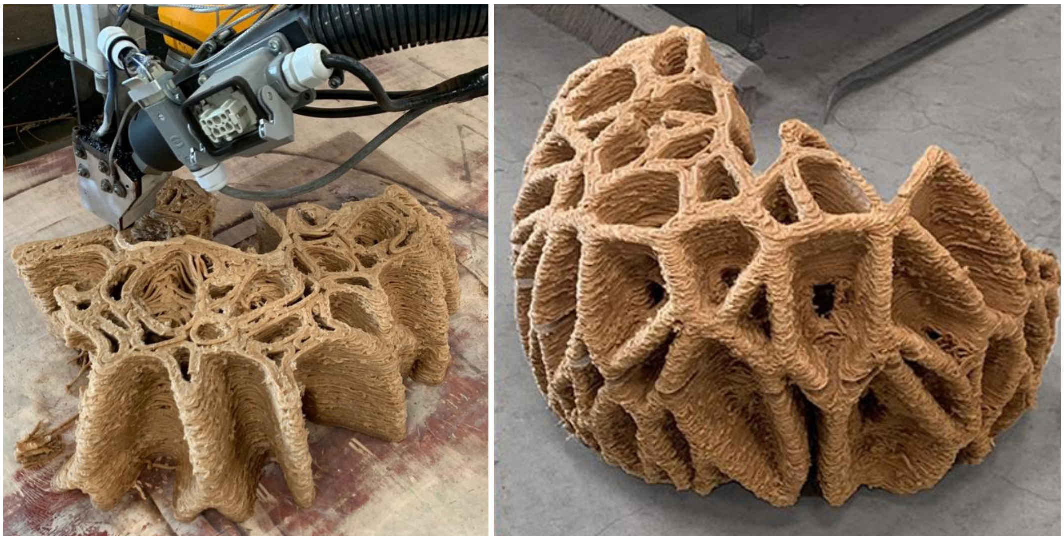

FIGURE 2 *D2RP process (left) and robotically 3D printed fragment of the 'planetoid' (right)*

Inside the 'planetoids', room is made for earth, plants and insects, small animals. The 'planetoids' interact with the conditions on site by serving as 'sponges' to preserve water, store heat from the sun, et cetera. The hull is made to a large degree from biodegradable materials. Their material properties represent various temporal realities: some may exist for weeks, months or years, others may last for several decades and may be overgrown by plants. Others may dry out or fall apart and become the genesis of new life in the soil. In order to interact with the process, the hulls contain sensors that show location, temperature, humidity, et cetera. Data is recorded and shared via the Internet, where changes detected in the 'planetoids' are visualized on a mobile application. The recorded data is made accessible to a wider audience via notifications, such as when the soil with plants needs to be watered by neighbours or passers-by. By watering them the humans interact with the 'planetoids' and this interaction is acknowledged by means of visual and/or audio feedback. This feedback loop between the ecological and socio-technical systems requires Design-to-Robotic-Production and -Operation (D2RP&O) approaches.

Design-to-Robotic-Production and -Operation

The D2RP&O processes (Bier et al., 2018) employed for prototyping the planetoid involve two aspects. While D2RP is implemented by means of parametric design and robotic production involving 3D printing with biopolymers using wood fibres[1] (Fig. 2), D2RO is introduced for integrating sensor-actuators in order to track the temperature and humidity of the microclimates within and around the 'planetoids'. The overall shape is informed by the various functionalities of the 'planetoid', from hosting plants, insects and small animals to

1 Robotic Building website: http://www.roboticbuilding.eu/project/d2rp-for-product-from-landscape-microruin-lab/

harbouring sensor-actuators and interacting with humans. These functionalities require a material design that accommodates variable sizes, densities and structural performances. Hence, an adaptive Voronoi mesh approach is adopted (Fig. 3).

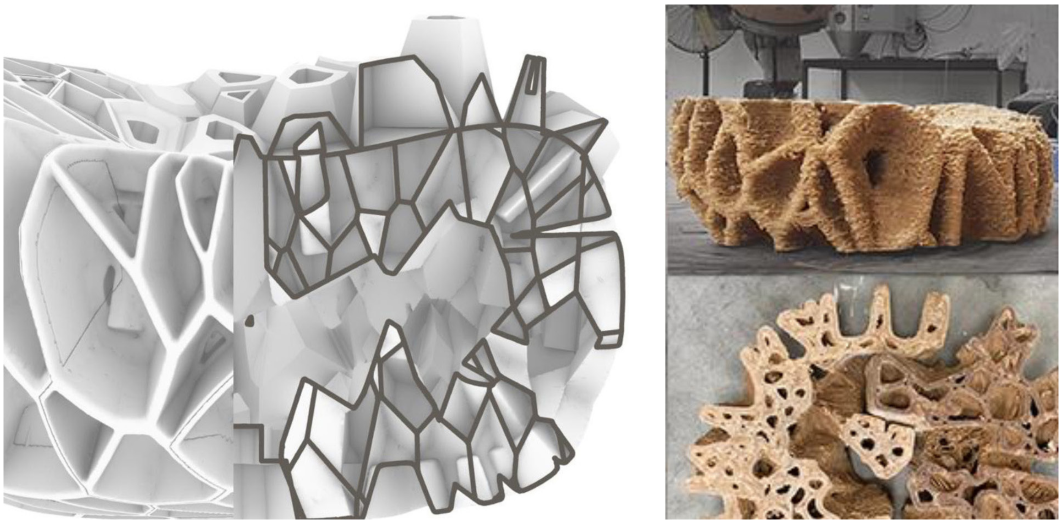

FIGURE 3 *The Voronoi structure facilitates the creation of convex and concave areas that offer opportunities for capturing or repelling sun and rain and fostering animal and plant species.*

While the D2RP part has already been completed (Figs. 1 and 2) the D2RO is still a work in progress. With the Voronoi (Fig. 3) creating the surface tectonics as well as the interior structure, which hosts the protected environment for animals and seed balls that develop into plants, the ‘planetoid’ creates opportunities for animal and plant species to dwell and grow. Depending on the location, the surface tectonics are designed to create ‘craters’ and ‘volcanoes’ that capture or repel sun and rain. Multiple plants grow from a single ‘planetoid’ and multiple sensor-actuators are integrated into the ‘planetoid’. Data is streamed to an app, which notifies users/potential visitors in real time and ‘invites’ them to interact with the ‘planetoids’ and their microclimates by irrigating or weeding them, even relocating them. Additional sensor-actuators are envisioned to track human movement and playfully facilitate interaction.

Sensor-actuator system

The integrated sensor-actuator system consists of various components that require further definition:

A. Sensing modules: each sensing module carries a unique identifier, defining its function as well as modes of functioning, including frequency of data collection and communication. Each ‘planetoid’ hosts several sensing modules, which can be added, maintained and modified individually. The sensors require a remarkably low amount of energy and can operate on a battery for several months.
B. One gateway collects, via Bluetooth, the data transmitted by all the sensing modules in its physical proximity. It broadcasts the sensor data, along with the identifier of the sensing module, to the LTE urban antenna. The transmitted data also contains information about the cloud service associated with this set-up as well as the credentials to access the cloud database.
C. LTE (Long-Term Evolution) networks that are available in most European cities via various commercial providers.

D Through the MQTT protocol the cloud database ‘subscribes’ to receive the data collected by sensing modules with certain identifiers. The data will be stored and made available for queries via any web-based application.

E Data made accessible to the users through either the QR code associated with the ‘planetoid’, or simply its placement. Gamified presentation of data is intended to be engaging and to lead to action.

In the future, the ‘planetoid’ will develop learning capacities in order to predict moments – depending on the patterns of human and non-human activities around the planetoids – when opportunities arise for interaction with the evolving nature (vegetation, insects, etc.) and humans. K-means and Hierarchical Clustering (HC) as established Artificial Intelligence (AI) methods will be applied to discern correlations between presence, movement, actions and weather variables, in order to be able to offer structured predictions of opportune interaction moments and to promote them through the app.

While interaction scenarios between ‘planetoids’ and humans have been sketchily outlined, an in-depth study of the implementation and scalability of the system requires further consideration. The goal is to engage users in interactive experiences that can realize some of the potentials of abandoned areas as public urban spaces. The system will be able to sense environmental parameters such as temperature, humidity and light, as well as information related to the presence and movements of humans, animals and insects around the ‘planetoids’. The main actuation will be in the form of mobile application notifications informing the inhabitants about the emerging activities around the planetoids or the need for their action such as watering the plants. Additional actuation is envisioned in form of lights (Fig. 4) and sounds that could engage visitors in a playful manner.

Discussion

Socio-technical interventions made in natural environments in order to improve bio-diversity are not new. Various projects involving artificial reefs and 3D printed scaffolding for micro-organisms (Gautier-Debernardi et al., 2017) have shown that eco-friendly solutions can meet the needs for increasing bio-diversity in various natural environments. Such systems are employed in natural environments that lack biodiversity and seem incapable of recovering on their own.

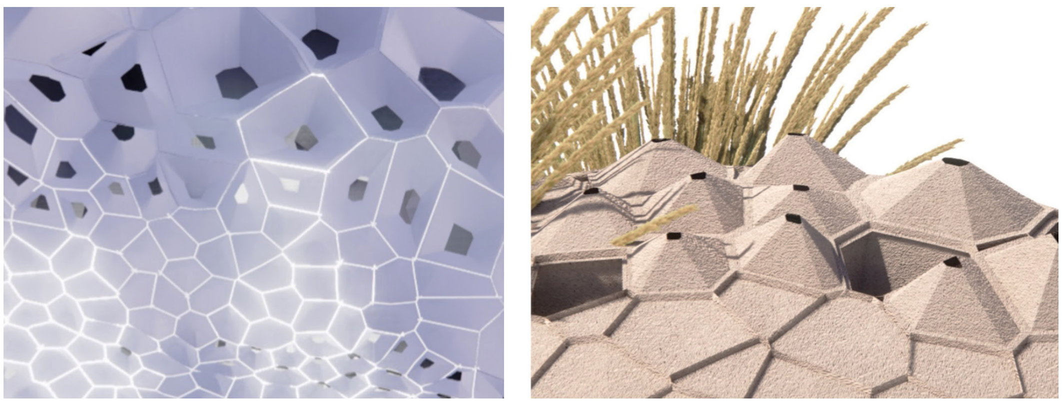

FIGURE 4 *Sensor-actuators (proximity sensor and light actuator) integrated in the Voronoi structure.*

The prototype described in this paper employs socio-technical systems not only to improve biodiversity but also to increase human–nature interaction as well as social acceptability and accessibility of leftover spaces. The expectation, based on studies of the micro-climates prevalent in the respective leftover space, is that the first prototyped 'planetoid' will establish new habitats for various animal and plant species. The development over time will be monitored and recorded on the 'bio-cyber-physical planetoid' app and results will be published in due course. The main hope is that by inviting potential visitors to irrigate the 'planetoids' or protect them from the sun, or playfully engage with them, a bio-cyber-physical feedback loop will be established, thus contributing to sustainable urbanism.

The novel opportunities offered by cybernetic social-ecological systems involve AI and rely on its ability to, in this case, identify correlations between the evolving nature, weather variables and the actions of humans in order to be able to offer structured prediction of opportune interaction moments and to promote them through open-access, web-based platforms and mobile applications. The established bio-cyber-physical feedback loop frames human and non-human agents as co-creators of processes and events in which agency is not attributed to one or the other but emerges in the interaction between them.

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2 Microruin Lab project: https://stimuleringsfonds.nl/nl/toekenningen/microruin_lab/

3 Cyber-physical Space wiki: http://cs.roboticbuilding.eu/index.php/Shared:FinalG1

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