Mould Racing, or Ecological Design through Located Data Games

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Abstract

Can a complex site, such as an urban park, be better understood through a game? Might this playful preparation be useful for design? In response to such questions, this paper discusses a practical project that structured design-oriented site research as a development, implementation and deployment of a locative mobile game in which designers learn by racing colonies of virtual organisms. The analysis of this experiment demonstrates that this approach can support creativity and provide benefits compatible with goals of ecological design.

Aims and Questions

Ecology studies the reciprocal relationships between all organisms as well as between organisms and their environments. A subsection of this field, urban ecology can be defined as the study of how ecological systems evolve in cities. Ecological design is an outcome-oriented approach, informed by these fields of study, that aims to integrate human intervention with ecosystem processes, typically, to minimize the environmentally destructive impact (Van der Ryn & Cowan, 2007, x). More ambitiously, design can aim to orchestrate beneficial human relationships with other organisms in the built environment (Danilo & Steiner, 2011) . Ecological design is neither a linear process of master planning, characteristic of human design, nor a process of trial and error involving variation and selection, as they occur in natural systems, but instead is a coordinated process of dealing with unexpected turns via experimental practice (Gross, 2010).

An important ambition of related approaches to design is to deal with whole ecosystems rather than with discrete objects, e.g., cf. deep design (Wann, 1996), ecological design (Orr, 2002) or transition design (Irwin, 2015). Such systems are characterised by emergent and unpredictable events, they are complex, locally specific and prone to change.

To be effective, this type of designing needs to undergo a range of perceptual shits (DeKay & Bennett, 2011): 1) from objects to relationships to subject–object relations; 2) from analysis to context to analysis–context–ground; 3) from structure to process to unfolding; 4) from materiality to configuration to pattern languages; 5) from parts to wholes to holons; and 6) from hierarchies to networks to holarchies.

Fig. 1. The compound world 1: the procedural events of the virtual simulation can be experienced on-site and in the presence of others, through mobile devices. Top: players disperse at the beginning of the game. Bottom: explore the site.

Fig. 2. The compound world 2: players move through the shared site independently, linked by the conceptual structure of the game.

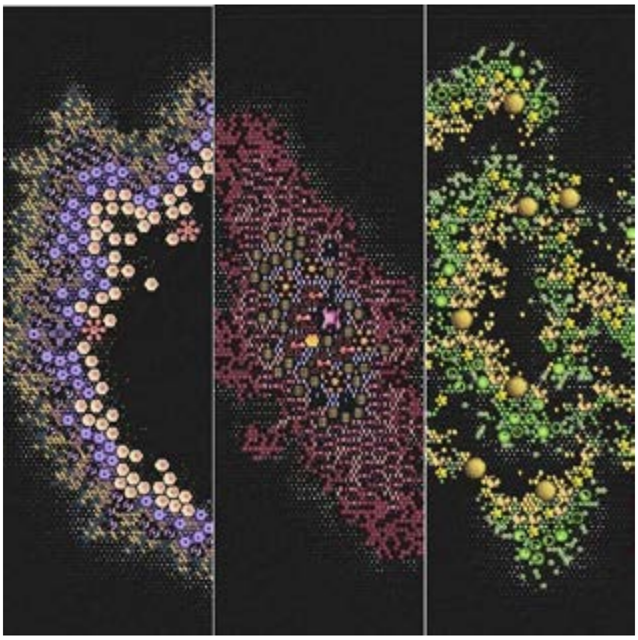

Fig. 3. Colonies 1: different types of cellular-automata growths in a context-free experimental environment.

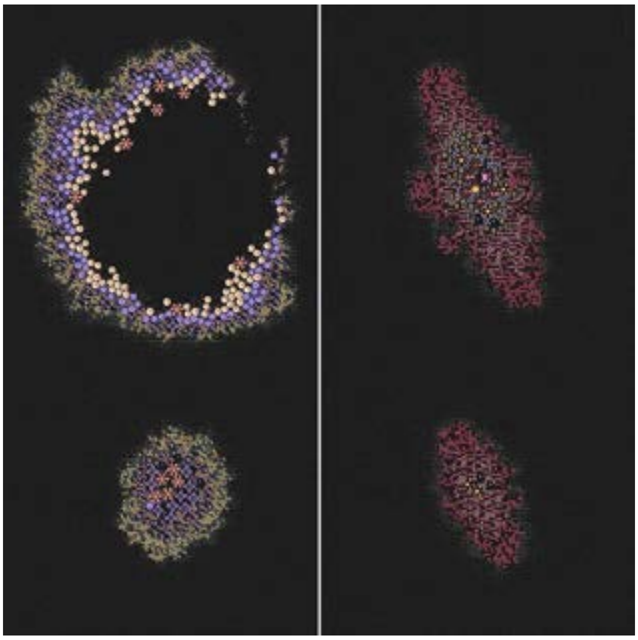

Fig. 4. Colonies 2: growth of two colonies with different aging rate and fecundity. Left: the Yellow expands quickly. Right: the Red colony grows more slowly.

In response, this paper proposes a contribution to an 'inspirational design environment' (Binder et al., 2011, 27–50) that can enhance such perceptual shits while informing them with evidence. Design environment is understood here as the totality of the circumstances that host the design process. In all contexts, but especially in ecological design, the design environment needs evidential input from a variety of heterogenous sources, including unusual stakeholders with differing knowledge systems. Participatory designing underpinned by the best of scientific knowledge become indispensable in engagement with ecosystems. How can scientific use of experimentation and experimental instrumentation inform the design process?

Experimentation is a method for uncovering surprising events. One particularly important example from applied, experiment-driven science is its use of epistemic objects. Epistemic objects (objects of knowledge) are abstract; they remain in continuous reconsideration and lack completeness (Knorr-Cetina, 2001; Rheinberger, 1997). This relative openness allows these objects act as catalysts for collaborative ideation.

This work extends the existing research on the use of visualisation technologies, interactivity and games 1) by using a game environment in support of ecological design and 2) by combining embodied experiences with generative simulations. The novelty of these contributions can be confirmed in reference to recent overviews of serious games (Laamarti, Eid, & Saddik, 2014; Lope & Medina-Medina, 2016) and to examples of recent work. The closest relevant category of the existing work can be defined as ‘data games’, or games where play involves engagements with real-world data, cf. (Friberger et al., 2013) or chapters 2–5 in (Nijholt, 2017). Existing approaches have attempted to 1) provide interactive access to visualised data to deepen understanding (Yi, Kang, Stasko, & Jacko, 2007); 2) encourage engagement by providing reward systems (Diakopoulos, 2011; Handler & Ferrer Conill, 2016); and 3) generate possible conditions by extrapolating from available data (Coulton et al., 2014; Dickinson, Lochrie, & Egglestone, 2015). The work presented here seeks to take such approaches further by supporting the design’s job of imagining possible futures from unavoidably incomplete premises.

The paper presents its argument in application to a specific case-study. This case-study focuses on the design of urban landscapes, a challenge that makes explicit the systemic complexities that are also characteristic of other design problems. This case-study aimed to:

1. Deepen the understanding of the environment
2. Encourage creative participation
3. Expand the repertoire of design methods

Design Experiment

The case-study is a design experiment that focuses on a socio-ecological system of the Merri Creek parklands in Melbourne, Australia. In this experiment, the Merri Creek park is complemented by a virtual environment that incorporates a custom-written geo-referenced cellular-automata engine that is visualized as a navigable space (**Fig. 7–5**) and accessed through mobile devices, such as smartphones. This digital environment supports an ecosystem of virtual life where plant-like species spread in reference to spatially distributed affordances. These spatial distributions reference the geometries and materiality of the physical site reflecting its grassy fields, muddy river banks, asphalted vehicular roads and pedestrian paths.

The result is a hybrid 'design environment' that is enhanced with epistemic objects that are relevant to ecological challenges but are uncommon in design. Such an environment allows participants to simultaneously inhabit and interact with the physical site and the virtual datascape experiencing ideas through their bodies and on location.

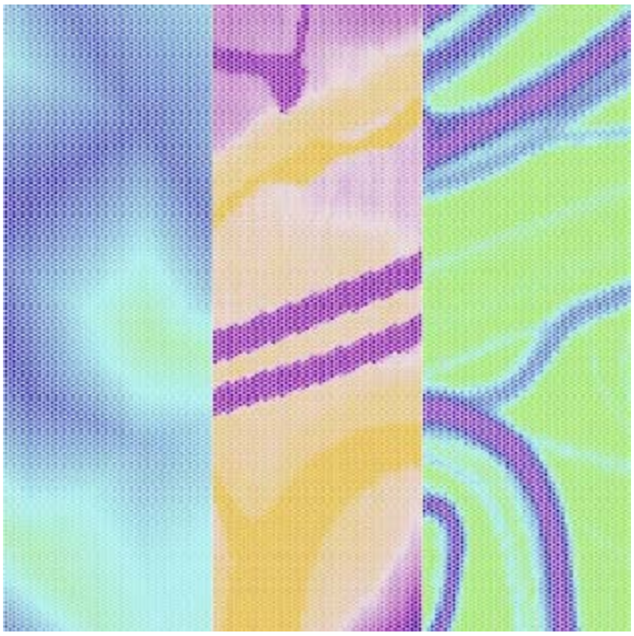

Fig. 5. Data maps 1: darker colours are cells with higher values. One map location is represented by different maps. Left: site moisture. Middle: ground permeability. Right: pedestrian movement.

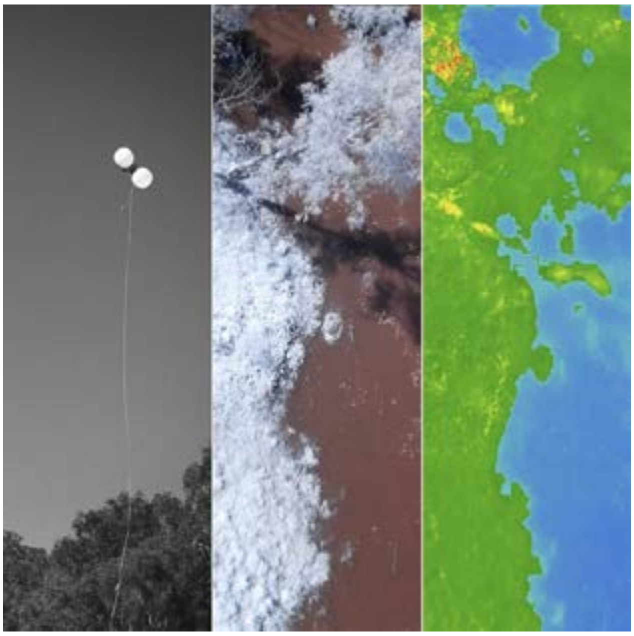

Fig. 6. Aerial mapping: left: balloon used in aerial mapping. Middle: an infrared image. Right: post-processing showing high photosynthesis activity in green.

Epistemic Object 1: Colony

In biology, a colony is composed of two or more individuals living in close association with each other. In design, an understanding of biotic communities such as colonies is important for their successful management. In response, the game represents the interactions between species, their environment and players as a range of properties (simplified here) that can lead to self-organization of these relationships into colonies.

The habitat properties are represented on a per-cell basis: 1) 'vegetation value' is the photosynthetic activity of vegetation, obtained through aerial near-infrared photography (**Fig. 6**), using balloons for elevation; 2) moisture is obtained from moisture sampling on site; 3) 'elevation' is the height above the sea level; and 4) 'ground permeability' expresses the amount and characteristic of ground cover, see **Fig. 4** for an example of distribution over the site. The organism properties are represented per species: 1) 'type' can be Red, Blue, Green or Yellow (**Fig. 3**); 2) 'age' can be: a) empty or dead; b) 'juvenile' (pre-reproductive); c) 'adult' (reproductive); d) 'senescing' (post-reproductive); 3) 'aging' can be faster in some species than in the others (**Fig. 4**); 4) 'reproductive success' varies between species and is influenced by their habitat; and 5) 'seeding' is based on probabilities weighted by habitat suitability. Player interactions take form of control over 'fertilisation': players can make the cell suitable to their species by physically traversing through them.

The growth pattern of the Green (right) results in (**Fig. 3**) with broken waves, in contrast to the continuous rings of the Blue (left). This pattern is a characteristic outcome of the low reproductive success and fast aging. Adult Green organisms are unlikely to seed into the surrounding empty cells before they become senescent and unable to reproduce. This process results in the characteristic gaps in its ring. In a more complex interaction (**Fig. 7**, left); a Red species grows along ground permeability gradients. It looks at the neighbouring empty cells and populates those sufficiently impermeable, resulting in a linear colony establishing itself along a length of road (**Fig. 7**, right).

This example demonstrated how an epistemic object 'colony' can be experiences through an interactive, located and embodied gameplay, leading to greater appreciation of the ecosystem dynamics and encouraging the shift towards the recognition of perceptual patterns of unfolding, as introduced above.

The subsequent discussion is divided into three parts that correspond to the key goals of the project introduced above.

Epistemic Object 2: Designer

In design, designer is a person that plans an entity prior to it being made. This is representative of well-recognised professional roles that ecological design aims to update and this project seeks to rethink design in terms of stewardship and redirection rather than explicit control.

In the game, designers, acting as players, are assigned a species. They can control growth of their colonies, but only indirectly. Player hold mobile devices that visualise the game state and record their location using Global Positions System. The game registers player's presence in a cell and adjusts the properties of this cell, making it into a suitable habitat for the player's species ('fertilisation'). Thus, players' ability to act as designers is made contingent on their understanding of their virtual species and their bodily interaction with the physical site. In an example of an interaction shown in **Fig. 8**, a designer racing Green notices an emerging Blue colony in the muddy area on the far side of the creek (**Fig. 8**, left). Confident that high moisture is her rival colony's preferred habitat, she seeks to disrupt its growth by sprinting to the bridge, crossing the creek and moving towards the aggregation of the competing species. Her species will move along the fertilised trail she leaves and surround her competitor (**Fig. 8**, right). Without any empty cells to expand into, the Blue colony grows old and disappears.

This example demonstrates how the game exposes its players to a new interpretation of a familiar epistemic object 'designer'. Even though the game mechanics of this prototype are deliberately simple, the resulting cognitive effect do encourage the perceptual shift from an understanding of the designers as pre-planner to that of the designer as steward that sets conditions to encourage ecosystem events without controlling them directly.

Epistemic Object 3: Fragmentation

In ecology, habitat fragmentation is the emergence of discontinuities in an organism's preferred environment. These discontinuities, often caused by urban and agricultural development, introduce conditions such as gaps, islands and edges into a habitat, with significant impact on species and ecosystem health.

In the game, the consequences of fragmentation are experienced as constraints on gameplay. In one instance, participants were taking a break to discuss their experiences after playing the game several times. A player racing Red told the group how frustrated he was with his species, which only grew on impermeable surfaces.

As seen in **Fig. 7**, the player most often encountered his colonies spreading along the roads crossing the site, which he felt made them vulnerable. Many times, he saw competing colonies occupying the entire width of a road, leaving no room for his to expand. An instance of this can be seen by the Blue colony blocking the path of the Red in the top right of the figure (**Fig. 7**, top right). Another agreed, noting that rounder colonies seemed more capable of adapting to change than linear ones, which could easy be disrupted by blockages. These conversations illustrate a perceptual shift to a standard concept in science, 'fragmentation', and the newly acquired awareness of its network effects. From gameplay alone designer-participants were able to understand that edges had significant impact and proximity to or frequency of edges resulted in the reduced resilience of their colonies.

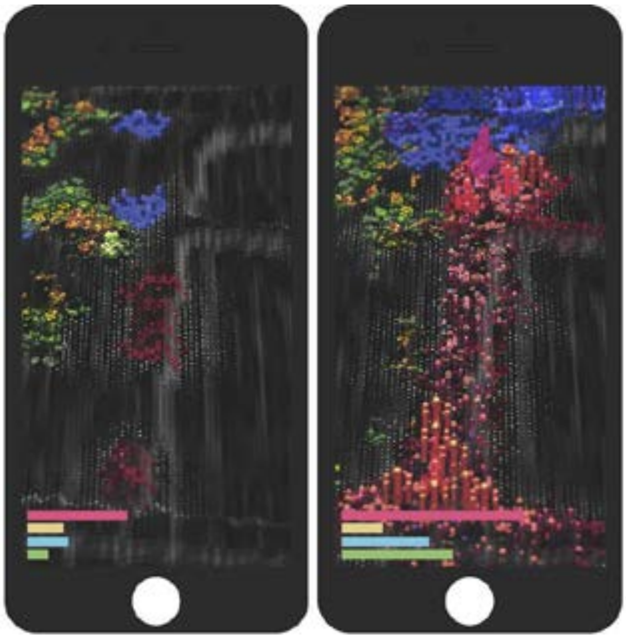

Fig. 7. Data maps 2: the simulated growths spread in response to the mapped data. In this instance, the Red colony thrives in concreted areas and can establish a large linear colony along a road cutting across the site.

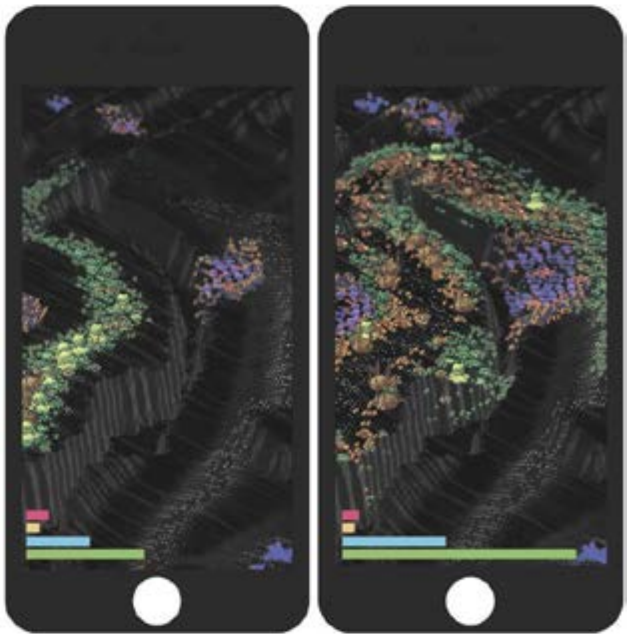

Fig. 8. Player agency: the trace left by the mobile device carried through the site affects the behaviour of the simulated growths. Here, a trace that runs across the bridge and through shrubs allows the Green colony to expand to both sides of the waterway, outmaneuvering a Blue aggregation.

Epistemic Object 4: Recruitment

In biology, recruitment is the process where juvenile individuals are added to a population. Continual recruitment is needed for an ecosystem to function as existing organisms senesce and die. Disrupting this process alters the composition of ecosystems, with significant future consequences. For instance, today's sustainable practices cannot bridge a gap left by low recruitment in the recent past, as can be seen, in the impeding massive loss of large old trees and the subsequent losses in the many species that depend on them.

In one post-game conversation a player responsible for racing the Green colony asked if she could play Red in the next round. Though initially happy to race a fast-reproducing organism, she was now tired of ensuring that all her colonies had sufficient fertilisation for expansion. This player hoped that there would be less pressure to closely monitor the opportunities for recruitment when racing colonies of slower-growing but longer-living species.

This example demonstrates how an ecologically-relevant epistemic object, recruitment, can be derived from gameplay by a designer-participant that is not only ignorant about the relevance of recruitment but is unfamiliar with this concept before entering gameplay.

Design Environment

In this paper, the term 'design environment' includes the totality of entities such as objects, concepts and instruments that are involved in the process of designing and are recognized as its outcomes. In this context, the hypothesis of the project is that an arrangement of the design environment that aims to introduce problem-specific concepts and language while shortening the distance between design representations and designed phenomena can result in deeper understanding of the challenges at hand.

For the experiment, the site was limited to a 200m^2 section of the park. As characteristic of all sites, this location has been shaped by many simultaneous processes. Examples of these processes include economic needs of the city producing a highway overpass, cultural influences resulting in sporting facilities, cycling routes and scenic picnic areas as well as activities that aim to restore natural wetland systems after several decades of degrading industrial use.

Seeking to reflect these overlapping intensities, the test site is discretised as a 300x300 grid, which is then populated by layers of numerical information about the parkland. The experimental environment includes properties that are described in Epistemic Object 1. These data sets (**Fig. 4**) have been selected to demonstrate the possible diversity of data types, data sources and data quality, see Epistemic Object 1 for details. Varying formats, extents, consistencies and resolutions can be combined to create a compound virtual environment (**Fig. 1**). This capability is significant because it supports ‘configurability’ (Binder et al., 2011, 50) – an important characteristic of all inspirational design environments. The configurability supported by this approach can be particularly powerful as it integrates intuitions of human designers with diverse numerical evidence and direct on-site experiences.

This grid becomes a virtual world when populated by cellular-automata simulations of plant-like organisms. An instance of the world is initiated with several species, distributed according to weighted probabilities. Without external intervention by participants, organisms multiply into adjacent empty cells and establish colonies. Individual organisms within cells progress through an initial expansive period, a mature phase, and a period of decay leading to disappearance, see Epistemic Object 1. Colonies with different behaviours, properties and preferences emerge in response to parameters controlling this life-cycle, resulting in a rich and dynamic virtual landscape. The experiment discussed here featured four distinct types of colonies tagged by colour (**Fig. 3**), also see Epistemic Object 1. In response to the contextual conditions, these colonies might spread rapidly and then quickly die off, grow more slowly as clumps, exhibit observable spatial preferences, and demonstrate emergent, partially predictable behaviours.

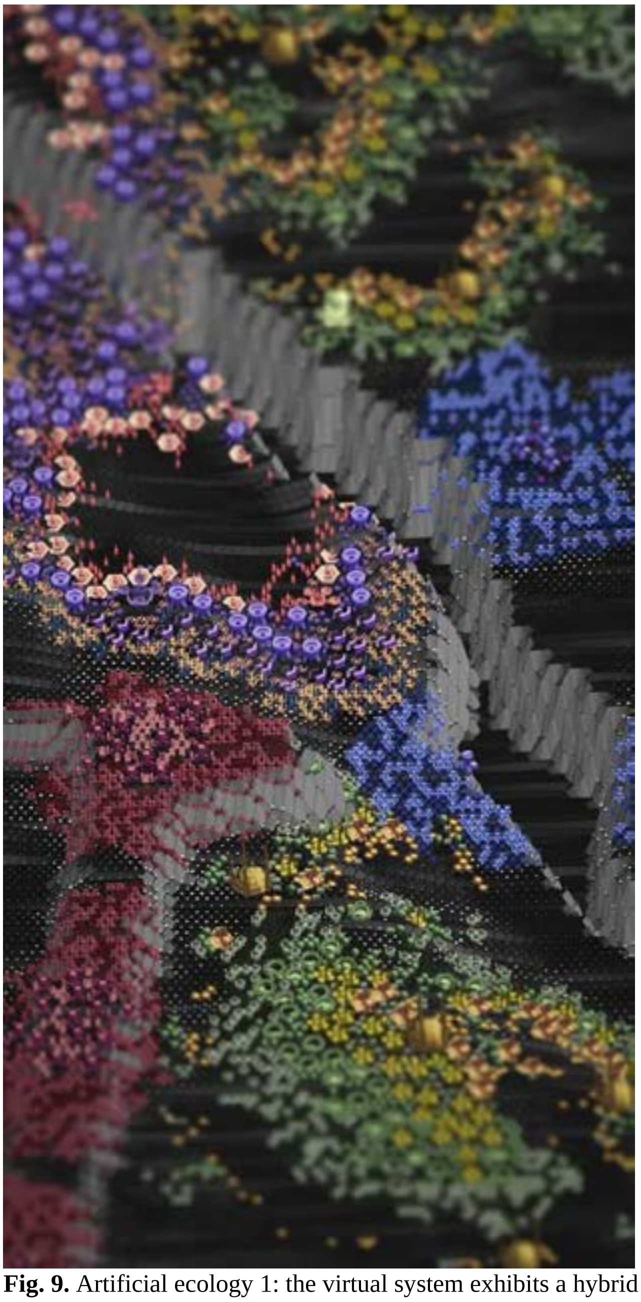

Fig. 9. Artificial ecology 1: the virtual system exhibits a hybrid ecology constrained by virtual and situated influences.

Each species is designed to prefer a spatial condition defined by the site properties. When a species is in its preferred habitat, its multiplication rate is accelerated. If all neighbouring cells are occupied, the colony has no place to expand and will soon die (**Fig. 11**). These rules support self-organizing growth patterns that can react to the site conditions in nonrepeating and surprising ways, without the need for pre-arranged and pre-situated events. This cellular-automata engine does not aim to simulate the site realistically. Instead, it emphasises the dynamic and incompletely controllable character of the design challenge, inviting reflection on the role of design and deeper engagement with the design situation. In this context, the simulation acts as an interpretative device that links heterogenous data sets, human expertise and immersive learning. These capabilities contribute to greater 'creative density' (Binder et al., 2011, 50), another important characteristic of inspirational design environments, by facilitating unexpected combinations of data and chance encounters at new locations, with its possible effects.

Simulations using cellular automate have been previously used to model urban or regional interactions. Even when they cannot reliably predict the future states, they are useful as devices that can map and visualise the scope of possibilities and link actions with potential consequences. The project discussed here sought to overcome the abstraction and the simplification that are unavoidable in computational models by narrowing the gap between the virtual and the physical worlds through the use of mobile devices.

Design Participants

This effect is achieved when the simulation is accessed on-site and experienced in parallel with the surrounding environment, fulfilling an important requirement of inspirational design environment that need to encourage holistic experiences to the 'genius loci' of target locations (Binder et al., 2011, 50). Prototype testing demonstrated new opportunities enabled by such embedding. For instance, this approach is useful for contextual assessment of available data. Incomplete or unevenly distributed datasets are common in practical situations. When a virtual environment informed by such data can be directly compared to on-site conditions, its quality can be more readily appraised and its import usefully reassessed, especially in the presence of other knowledgeable participants.

Dissonances between different forms of representations, interpretations and experiences can be beneficial because they disrupt habitual assumptions and encourage contributions for a broader range of voices thus supporting 'connectivity' – another essential component of the inspirational design environments (Binder et al., 2011, 50). To emphasize the virtual environment's capacity to support participative critical engagement and creativity, the access to the simulation is structured as a game. Within it, each species is represented by a set of geometries that change with maturity. The result is a visually rich world where relative states of each colony can be understood quickly and intuitively (**Fig. 7–Fig. 8**).

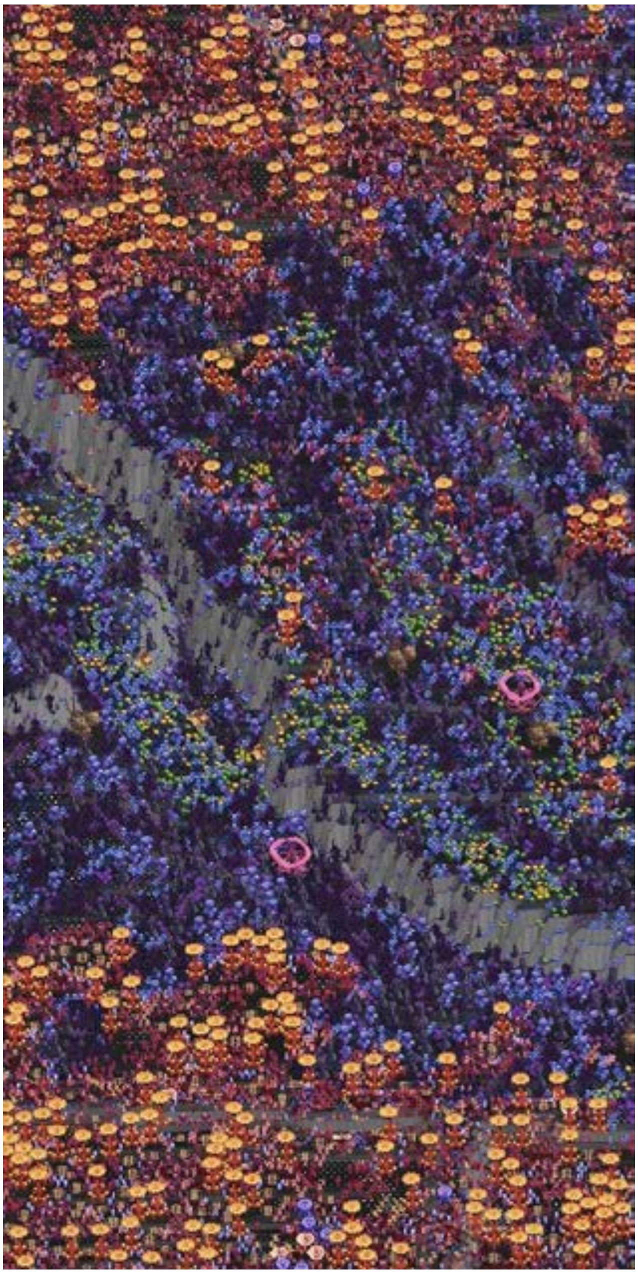

Fig. 10. Artificial ecology 2: one set of conditions (compare with the previous image) can result in substantially different ecologies.

Several players begin at the same time, in one location and are given control of one species in the simulation. The objective of the game is to make this species most populous. A round lasts ten minutes. Mobile devices show the state of the virtual ecology and the bar chart of the population numbers (**Fig. 7**). When a round begins, players quickly disperse searching for locations where their species might thrive. By physically moving across the site, players alter their location and intervene in its dynamics. Their trail leaves a residue that temporarily converts an empty cell into a habitat suitable the player's species, facilitating multiplication, see Epistemic Object 2 for an example.

Loosely structured, the game can be played in multiple ways. A group of three might decide to work with a single mobile device. Others form looser coalitions or rivalries: they observe each other but operate separate devices and are not aware of what happens on other participants' screens unless they ask. Each phone runs an isolated instance of the simulation but species behaviour, underlying data maps and site attributes are shared across instances, enabling comparisons, competition and cooperation, see **Fig. 2** for an example of parallel play.

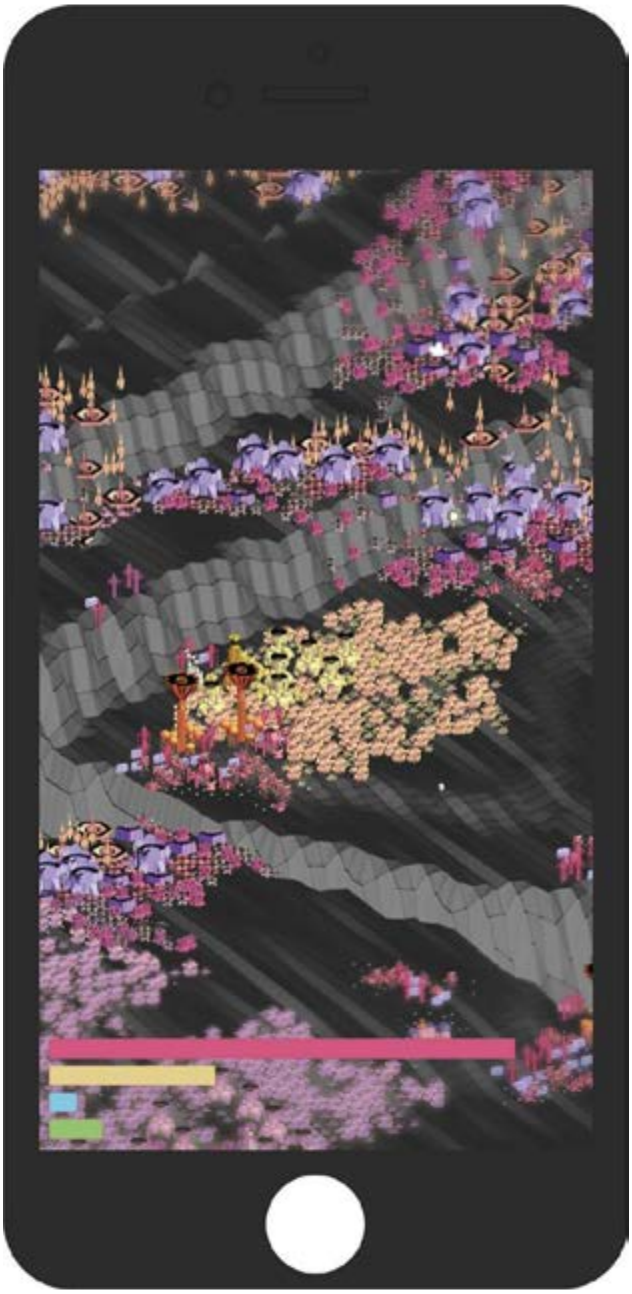

Fig. 11. Game event. Blocked on most sides by the Red, the central Yellow colony has limited room to expand. Without help from the player, it will soon die.

Once the ten-minute game cycle is complete the final population numbers are displayed (**Fig. 7**) and players return to the central point to discuss the outcomes. One person might complain that the Green easily overtakes the other species, with others nodding in agreement. Sometimes the initial seeding gives an advantage to a species. Another might pass her phone around, showing the Blue overwhelming everything else. Suggesting where they think each species grows best, some want to play another round – eager to see a new starting arrangement and test their just-acquired knowledge of the site. Everyone is allocated a different species, and another round begins. Cast as players, individuals are encouraged to take unusual actions within a shared structure that encourages them to compare and discuss their experiences and understandings.

The next section explores how such interventions can be used as methods to expand design beyond the creation of desired states and towards continuous and iterative negotiation of many forces characteristic of ecological design, see Epistemic Objects 3 and 4.

Discussion and Conclusion

The project's third objective has been defined as an attempt to expand the available selection of design methods, especially in relationship to such concepts as ecological design and its core principles: 1) place-specific solutions; 2) reliance on ecological accounting; 3) designing in partnership with nature; 4) inclusive participation; and 5) foregrounding of the natural processes (Van der Ryn & Cowan, 2007).

The goal of growing design solution from the specificity of concrete places is far from trivial as comprehensive understandings of what comprises such places are not readily available. The proposed approach has the potential to deepen and expand the place-specific research that typically occurs at the beginning of design.

The experiment has also demonstrated that situated simulations can contribute to integration of ecological accounting into design practices by providing a forgiving platform that can combine diverse datasets, provide an interpretative layer that can be compared to on-site conditions and motivate on-demand, ad-hoc data collection.

This commitment to deeper design research also contributes to the goals of design with nature and foregrounding natural processes that is further strengthened by deployment of simulation engines that can model real-world interactions. Deployment of such models can inform the initial, intensive stages of designing and be productive during the ongoing management of change. In addition, it invites design participants to reconsider their role in the design process by emphasising an understanding of designing as the continual negotiation of dynamic relationships rather than the creation of steady states.

In summary, the paper demonstrates the deployment of location-specific mobile games with integrated simulation of ecological process can lead to successful integration of important epistemic (knowledge) object from science and to relevant perceptual shifts in the disposition of participating designers.

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Authors Biographies

Stanislav Roudavski studies and designs technologically sustained places. His current practice-based research integrates organizational techniques of architecture, unpredictability and richness of performative situations, creative capacities of computing, visual languages of the moving-image arts, dramaturgy and spatial narrative.

Alex Holland works with kites, games, prison playgrounds and trees. He investigates the digital and physical characteristics of contemporary environments and the design opportunities arising at their intersection. Holland's current research looks at how techniques of computing can make contemporary design more participative.

Julian Rutten's research is situated at the intersection of culture, nature and technology. It explores how the concept of place evolves under the influence of technology. Rutten's qualifications include landscape architecture, mechanical engineering and robotics, deployed in the context of interdisciplinary design.