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AN ONLINE TOOL TO DESIGN CUSTOM HABITAT-STRUCTURES WITH AND FOR TREE-DWELLING SPECIES

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1. INTRODUCTION

This paper presents novel approaches to designing with and for tree-dwelling species. As a team of designers and ecologists, we introduce an online tool that supports implementation of artificial habitat-structures for birds, mammals, and other organisms. We respond to the need for interdisciplinary and innovative research to address mass species extinctions [1], support urban biodiversity [2], and ameliorate conflicts between human and nonhuman beings [3]. Design for nonhuman clients poses significant challenges that concern an increasing number of built-environment professionals [4–6]. Recent efforts utilise computer-aided design and manufacturing to produce habitat structures with geometric and material qualities that can benefit many different species. Examples of such artificial habitat-structures include 3D-printed reefs for fish [7], machine-milled façades for algae [8], and complex perch-structures for birds [9].

This paper focuses on artificial tree-hollows that support nesting and denning. Many animals do not make their own hollows and instead rely on those that form naturally. However, it takes decades [10] or even centuries [11] before trees host suitable natural hollows. Shortages of large old trees in urban and agricultural areas threaten many hollow-dependent species [12]. In response, conservationists install artificial hollows like nest boxes [13]. Community-led initiatives to supply artificial hollows are popular but do not always have the best designs. Industrial manufacturing techniques result in artificial hollows that are easy to produce yet significantly different to natural habitat-structures [14,15]. Standardisation and mass-production limit opportunities to adjust designs for local conditions such as available host-structures, species-specific behaviours, climates, or materials. Some artificial hollows can be difficult to place in suitable areas on trees, fail to attract target species, overheat animals inside, or break soon after installation [16–18]. Computer-aided design and manufacturing can tailor artificial hollow designs but require specialised equipment and expertise that are usually not available within community-led projects [19]. Build-your-own nest-box guides [20], community-led nest-box installations [21], and cultural associations with hollows [22] illustrate the importance of designing artificial hollows that engage human communities.

Therefore, this paper asks: what tools can help develop hollows that are both bespoke and accessible to human communities? We see opportunities to address this question by connecting computer-aided design with participatory design and democratic making. Participatory practices generate, test, and refine designs in collaboration with communities, stakeholders, or potential users [23]. At the core of participatory design are ideas of democracy, or the right for everyone to participate in matters that might affect them. Therefore, participatory design can and should include nonhuman stakeholders [24,25], such as birds, bees, and flowers [26]. Online configurators offer exciting potential for customisation through more-than-human participation, and democratisation through open-source technologies. Online configurators are websites that allow non-designers to customise computer models to suit their unique circumstances. While online configurators usually aim to sell products [27], such as furniture [28], Bee Home shows how such platforms can democratise the design of habitat structures by making them publicly accessible and freely available [29]. This paper explores how online configurators can usefully integrate human and nonhuman participation in the development of artificial hollows that suit place-specific circumstances.

2. METHODS

We developed and tested an online configurator for artificial hollows with both human and nonhuman users through case-studies in Trentino, Italy and Melbourne, Australia. The configurator provides several adjustable parameters that guide non-designers to customise and build artificial hollows [Figs 1–2]. Both high-end (professional) as well as accessible (do-it-yourself) options are available to suit different sites, target species, and human constraints.

Figure 1. Use of the configurator. Left: the interface on laptop. Right: the artificial-hollow model in augmented reality on mobile.

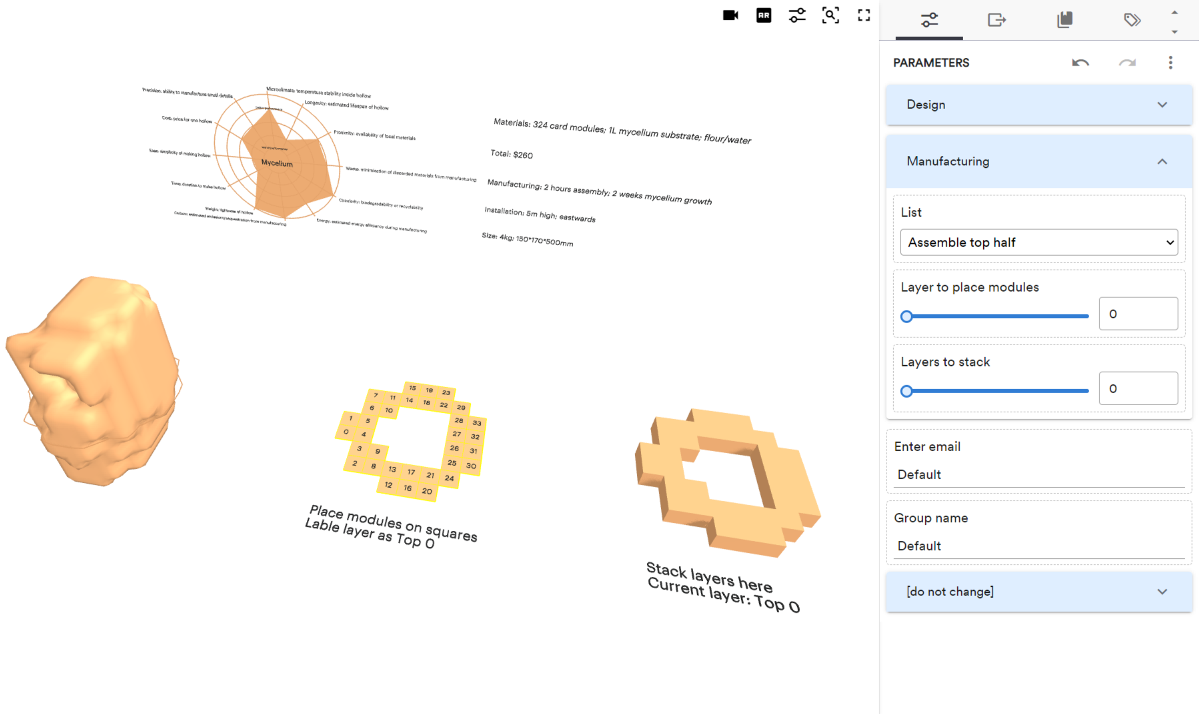

Figure 2. Interface of the configurator. Left: a model of the artificial hollow. Top: details on the hollow's performance including cost and required materials. Bottom: guides for do-it-yourself assembly. Right: parameters to adjust and order hollows.

2.1. CASE-STUDY 1, TRENTINO: NONHUMAN PARTICIPATION AND PROFESSIONAL MAKING

The case-study in Trentino aimed to develop approaches within the configurator for (1) customising designs with nonhuman stakeholders and (2) manufacturing hollows that are appropriate in different contexts by using professional techniques. First, we conducted a design experiment which used computer-aided design and simulation to propose hollows that respond to the needs of local owls and mosses [Figs 3–4]. Second, we manufactured a range of artificial-hollow prototypes using biologically based materials (soil, hempcrete, mycelium, wood, plastic) and computer-aided techniques (augmented-reality, laser cutting, 3D printing) [Figs 5–6]. We deployed these prototypes as public exhibits and assessed each hollow's environmental sustainability, feasibility of making, and suitability for the target ecosystem.

Figure 3. Precedents for design: fungi, bio-receptivity, site features, hollows, and patterns. Top left: bracket fungus on site. Top middle: an owl in a woodpecker hollow with a bracket fungus above (Gary Schultz). Top right: a computer model of a mushroom (Laurent Delrieu). Bottom left: bryophytes on site. Bottom middle: an artificial hollow made of mycelium and covered with mosses (Natalia Piórecka). Bottom right: a wall tile with algae that cleans wastewater (Brenda Parker, Marcos Cruz, and Shneel Malik).

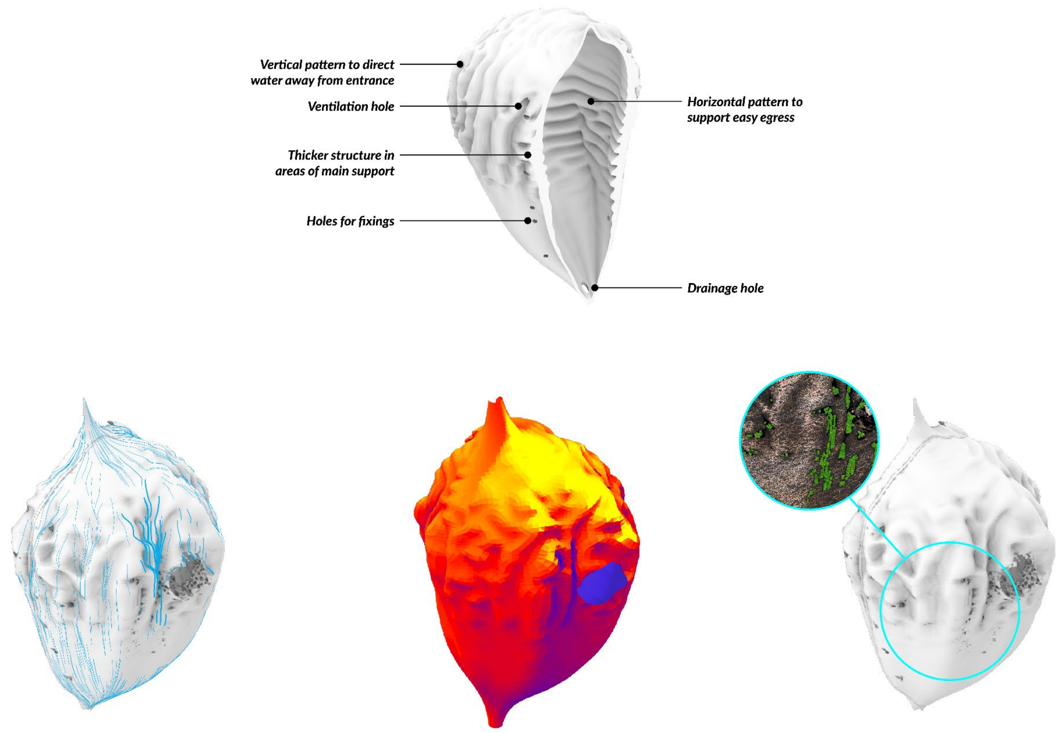

Figure 4. Artificial-hollow design and simulation. Top: pattern runs horizontally inside to support owl climbing, and vertically outside to guide water away from the entrance. Bottom: pores in moist (left) and dark (middle) areas to support mosses (right).

Figure 5. Artificial-hollow prototypes including soil, hempcrete, mycelium, plywood, plastic, and a log with a woodpecker hollow.


Figure 6. Prototype installed on a silver birch tree (*Betula pendula*) in Monte Bondone, Italy.

2.2. CASE-STUDY 2, MELBOURNE: HUMAN PARTICIPATION AND ACCESSIBLE MAKING

The case-study in Melbourne aimed to test the approaches provided by the configurator for (1) customising designs with human stakeholders and (2) manufacturing hollows using do-it-yourself (or together) guides. We trialled the configurator in a public hollow-building workshop that involved high-school and university students, Indigenous land-managers, volunteers for environmental initiatives, and local residents [Fig. 7]. First, participants selected and customised designs for a local species. Participants could add or edit entrances, predator guards, roosting platforms, and host-structures (i.e., trees or buildings). Second, participants followed the configurator's assembly guides to make the hollows from cardboard modules inoculated with mycelium. Subsequent work will report on the experiences of the participants and integrate their feedback into the development of the configurator.

Figure 7. Testing the configurator in a public hollow-building workshop. Left: Using augmented reality-goggles to assemble hollow (Alex Quan). Top-right: Designing a custom hollow using the configurator (authors). Bottom-right: Collaborative assembly of a hollow following the configurator's guide (Alex Quan).

3. RESULTS AND DISCUSSION

3.1. CASE-STUDY 1, TRENTINO: GEOMETRICAL INNOVATION AND MATERIAL SUITABILITY

The design experiment in Trentino established (1) innovative approaches for translating nonhuman needs into artificial-hollow designs and (2) multiple manufacturing options that can suit different contexts. First, the design experiment demonstrates how geometries can respond to several ecosystem features including different species, host-structures, and weather. Second, information gathered from the prototypes allow configurator users to consider trade-offs between options and select context-appropriate hollows [Fig. 8]. For example, mycelium is suitable for those who prioritise sustainability, have more time, are targeting species that change hollows frequently, or need fire-resistant materials in areas of cultural burning. Further research is needed to assess the hollows across their entire lifecycles when deployed at scale and reinstalled over long timeframes.

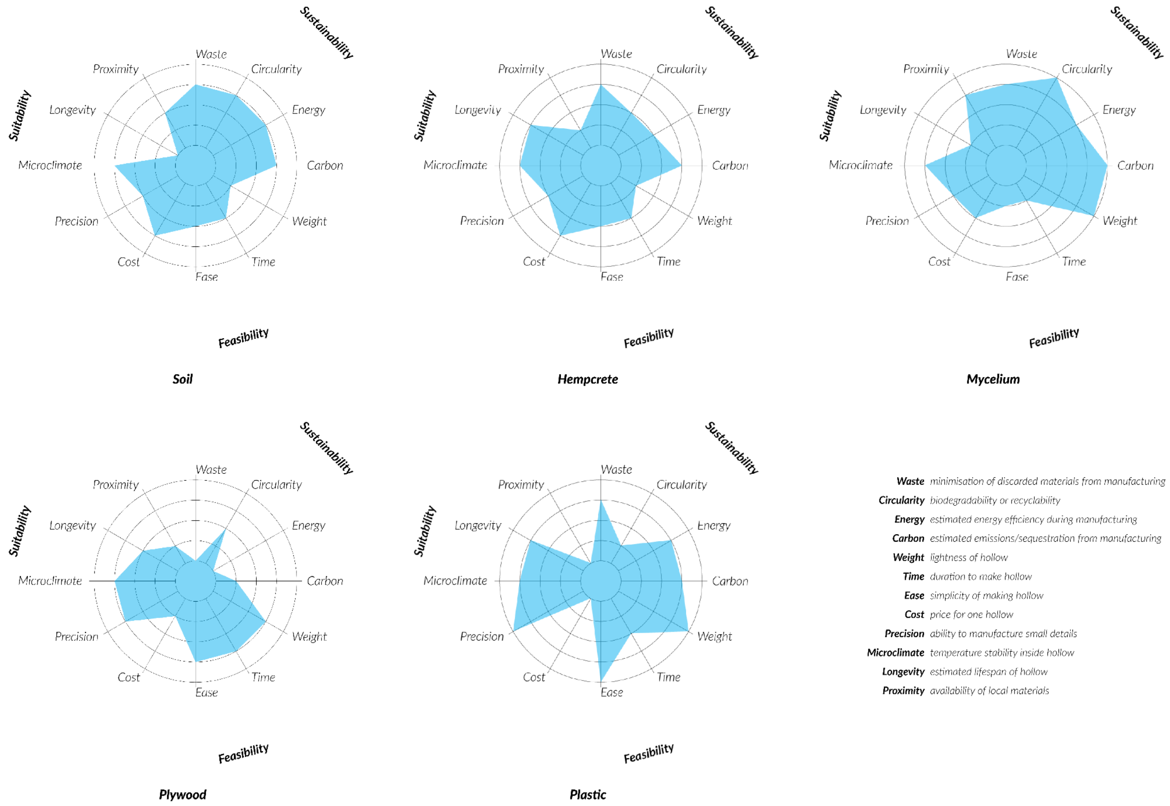

Figure 8. Assessment of each hollow’s suitability for target ecosystems, environmental sustainability, and feasibility to produce.

3.2. CASE-STUDY 2, MELBOURNE: LOCAL KNOWLEDGE AND HUMAN ENGAGEMENT

The hollow-building workshop in Melbourne demonstrates how an online configurator can (1) integrate local knowledge into artificial-hollow designs and (2) engage human communities of different ages and abilities. First, the configurator allows users to customise designs based on their unique experiences with the site and observations of target species. Such customisation is significant because animals of the same species often have regionally specific behaviours or experience different climates. Second, the configurator makes advanced technologies and materials more accessible by providing guides that are easy to follow. Tools and activities that are fun, exciting, and easy to partake in are useful to encourage participation in environmental initiatives. Future work will continue to add and refine designs within the configurator based on feedback from human users and use of installed hollows by nonhuman users.

4. CONCLUSIONS

Our case-studies contribute practical design experiments to a growing body of research that aims to involve nonhuman as well as human stakeholders in design. These cases show that combining computer-aided design with participatory, democratic design can aid the production of artificial hollows that suit specific ecosystems, are sustainable, and remain accessible to non-designers with different skills or resources. The configurator can integrate knowledge and expertise of both human and nonhuman stakeholders into the design, manufacturing, and deployment of artificial hollows. Adjustable parameters enable designs to respond to local cultures, resources, user preferences, climates, existing structures, and management needs. The configurator has the capability to assist residents to create habitat structures in backyards, community conservation groups to add habitat structures within parks, and developers or local councils to plan for artificial-hollow integration into larger habitat-restoration projects. These outcomes advance the goals of biodiversity-inclusive design and design for multispecies cohabitation.

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