Coupling Distinct Paradigms of Deposition-Based Construction for the Production of Co-occupied Boundaries

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Introduction

By definition architecture is distinguished from natural systems. Architecture is a cultural product that aims to provide varying degrees of isolation and protection from the world ‘outside’ and provides an artificial context to frame human activities.¹ Yet, despite this distinction, throughout the history of architectural production designers have looked to natural systems for inspiration to inform both the figurative and functional aspects of architecture and its production.²,³

The project described in this paper breaks with this orthodox tradition of ‘bio-inspiration’. Rather, it aims to investigate the direct coupling of architecture to natural living biological systems – specifically social insects (Fig. 1). This is a nascent research territory that has very few precedents to date, the most notable being the Silk Pavilion.⁴

Figure 1  Hybrid construction combining 3D printed artifact and self-organised deposition of bee-cornb.
Two Paradigms of Construction

Social insects are capable of producing highly complex structures with sophisticated spatial differentiation to support social and environmental goals. On occasion, these structures are comparable in scale to human architectural constructs. Research has established that the structures of social insects emerge out of local-interactions between individuals with no a priori design intent. They are self-organised.

The design and construction of architecture generally operates from a top-down paradigm in which design intent frames specification. This is largely determined prior to the co-ordinated efforts of construction. In addition, construction is generally conceptualised as a discreet phase of production aimed at producing an ‘end-point,’ after which occupation and use can begin.

The conceptual challenge of the project lies in developing an approach that couples these two distinct paradigms of construction. Our approach differentiates itself from that of the Silk Pavilion by producing volumetric scaffolds, rather than planar frames. Our scaffolds are fabricated using 3D filament deposition printing. The scaffolds are then ‘embellished’ through the self-organised construction of bee colonies, thereby leveraging the potential for an architecture to exhibit adaptation through continual construction.

3D Filament Printing

The project employs 3D filament printing technology for the production of the designed architectural components. The technology permits the production of highly porous yet robust artefacts to be constructed in organically derived materials – in this case the corn-starch derivative PLA. G-code for instructing the machine’s toolpaths and other control parameters is authored directly from design data, rather than relying upon proprietary translators that tend to encode assumptions about build strategy (Fig. 2a). This significantly increases authorship and opens new aesthetic potentials as fully 3D toolpaths can be generated. Gravity can therefore be fully exploited as a manufacturing parameter in concert with conventional controls over extrusion temperature, toolpath velocity and flow rate, to produce voluptuous filament draping and internal structures that are both porous and geometrically complex (Fig. 2b). A systematic investigation has established robust machining parameters allowing the investigation to progress into an exploration of design potentials.
Figure 2a  Deposition G-code is authored at the level of individual toolpaths. Control of parameters is informed through a systematic study.

Figure 2b  Deposition G-code is authored at the level of individual toolpaths. Control of parameters is informed through a systematic study.
Focused Design Target

To establish and test the computational chain between design and production, a focused design target is set within an overall architectural objective – the design of an educational space for a hypothetical urban context. The space is co-occupied by bees and urban dwellers with the aim of demonstrating new symbiotic potentials engendered through a reconsideration of architectural fabric that is both designed and emergent by leveraging the construction capabilities of bees. The focused design target is a column – an architectural element that has a structural role but also an intimate and sculptural role to occupancy as it can exist freely within interior space. Together with its structural role, it is designed to accommodate a bee family within its porous interior. The computational design of this element commences with the definition of a generic design volume and the specification of principle loading regions. A topology optimisation method establishes a minimum material solution that satisfies the structural demands. Additional material is then specified to define habitable cavities, routes and boundaries for bee occupation within the column (Fig. 3).

Figure 3 Authorship at the level of individual toolpaths opens new aesthetic and performance potentials for 3D filament printing.
Live Experiment

To test the hypothesis that 3D printed artefacts might provide a suitable environment for bees to colonise, an 8 month old bee family with approximately 500 bees was introduced into an experimental observation enclosure at the start of May 2016. The enclosure is a 50 cm edge-length clear Perspex cube containing a 3D printed artefact with a porous hexagonal interior structure suitably scaled for the bees, and horizontal rails to support the existing frames that the bees occupy.

The experiment is still ongoing, but after a three month period the bee colony has grown significantly in population (we estimate a doubling of the population) and in constructed honeycomb. There is evidence of the 3D print having become incorporated into the natural honeycomb structure and honeycomb being introduced into interior portions of the 3D print (Fig. 4), but as yet no evidence of the bees actually inhabiting the 3D print. It is assumed that this is due to the large available volume within the observation box that allows free growth of the bee’s own structures.

Further Work

The co-occupied boundaries project establishes the conceptual architectural ground together with preliminary investigations and results that explore the potential for coupling synthetic designed construction methods with the self-organised construction methods of social insects, to produce new forms of architectural boundary.

From these preliminary studies we see the need to establish more rigorous methods of observation of bee colony growth through continuous sensing, the need to investigate methods for steering the self-organisational capacities of bees and the potential for establishing stronger symbiotic performance benefits between the occupying species such the as adaptive regulation of thermal environments.

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Deposition G-code is authored at the level of individual toolpaths. Control of parameters is informed through a systematic study.

Endnotes

CITA is an innovative research environment exploring the intersections between architecture and digital technologies. Identifying core research questions into how space and technology can be probed, CITA investigates how the current forming of a digital culture impacts on architectural thinking and practice. CITA examines how architecture is influenced by new digital design – and production tools as well as the digital practices that are informing our societies culturally, socially and technologically. Using design and practice based research methods, CITA works through the conceptualisation, design and realisation of working prototypes. CITA is highly collaborative with both industry and practice creating new collaborations with interdisciplinary partners from the fields of computer graphics, human computer interaction, robotics, artificial intelligence as well as the practice based fields of furniture design, fashion and textiles, industrial design, film, dance and interactive arts.