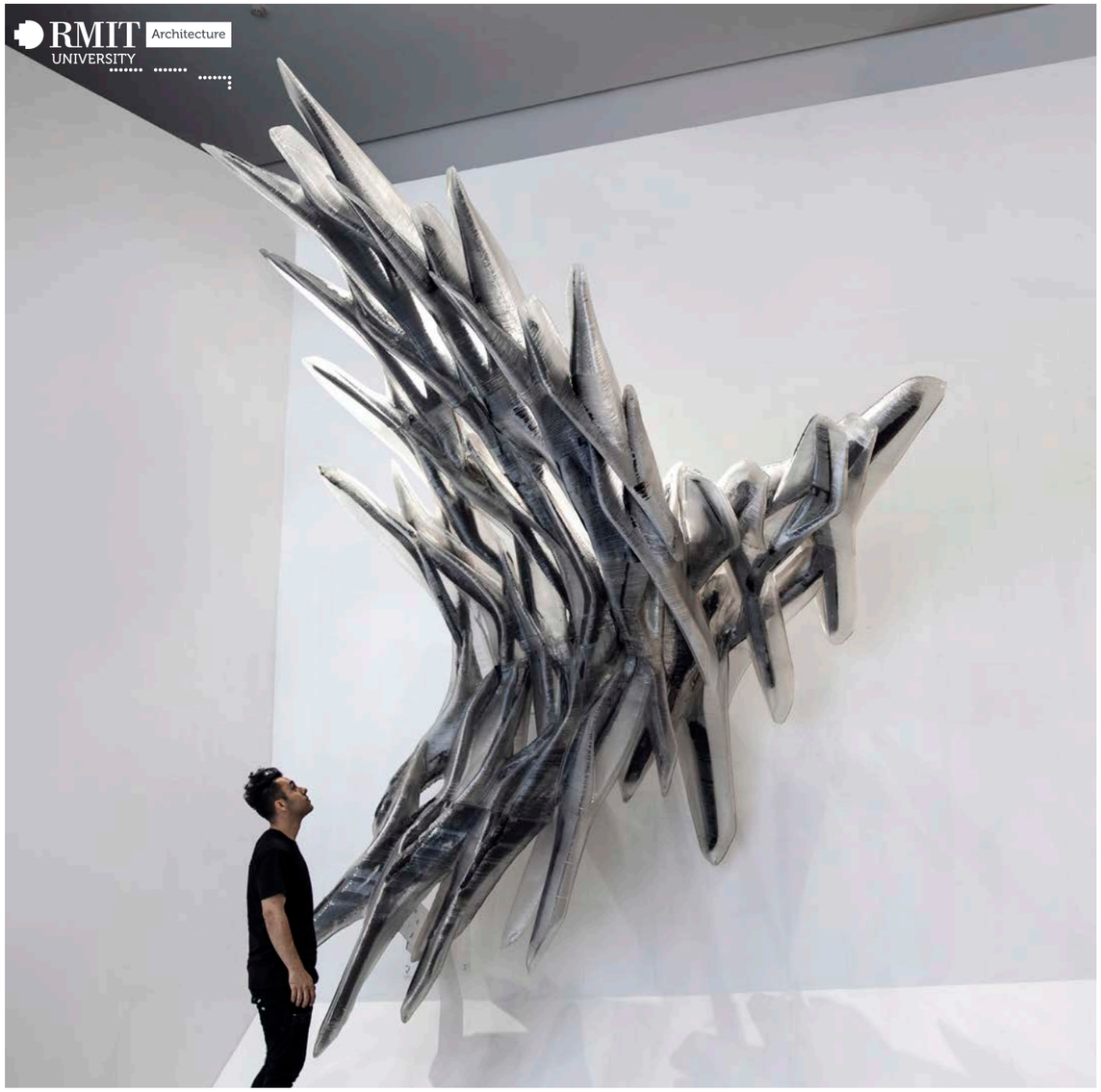
RMIT UNIVERSITY Architecture

ROBOTIC FORMATION LAB

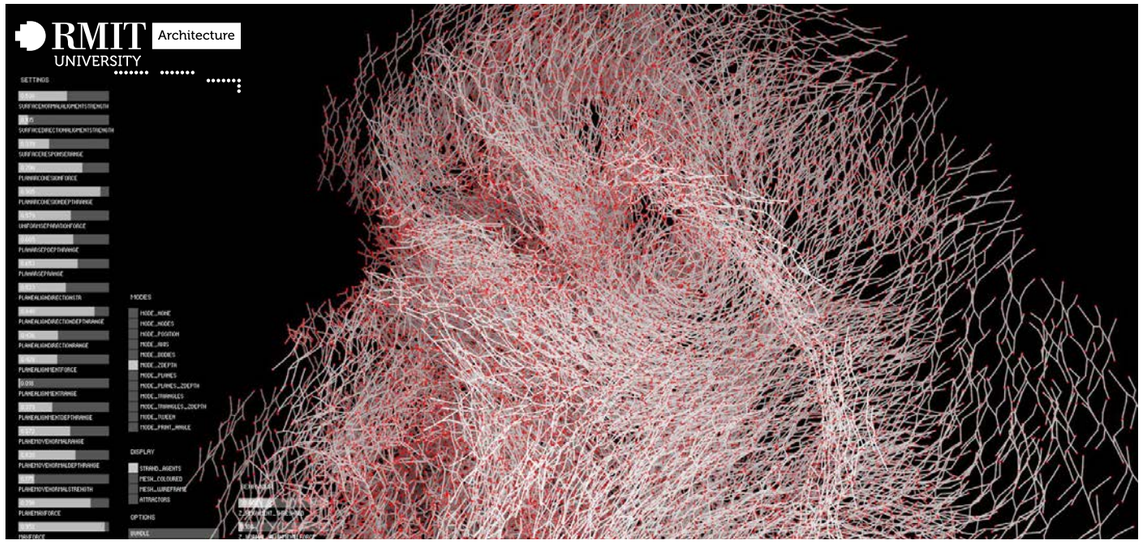


↑
Cloud Affects, Shenzen Biennale, Tectonic Formation Lab, 2020. Experimental design research is tested through this type of prototypical demonstrator project, where innovative techniques are pushed to their limits.

The RMIT Architecture Tectonic Formation Lab is dedicated to exploring the architectural design implications of emerging technologies. In particular, the lab develops and leverages computational design processes and robotic fabrication techniques to develop innovative architectural tectonics. We undertake both experimental design research and applied research through industry partnerships.

We work closely with industry partners to understand what innovations are able to transform their business and disrupt their industry. We collaborate to develop new techniques and technologies and to translate these to the point of commercialisation within industry.

LAB OVERVIEW



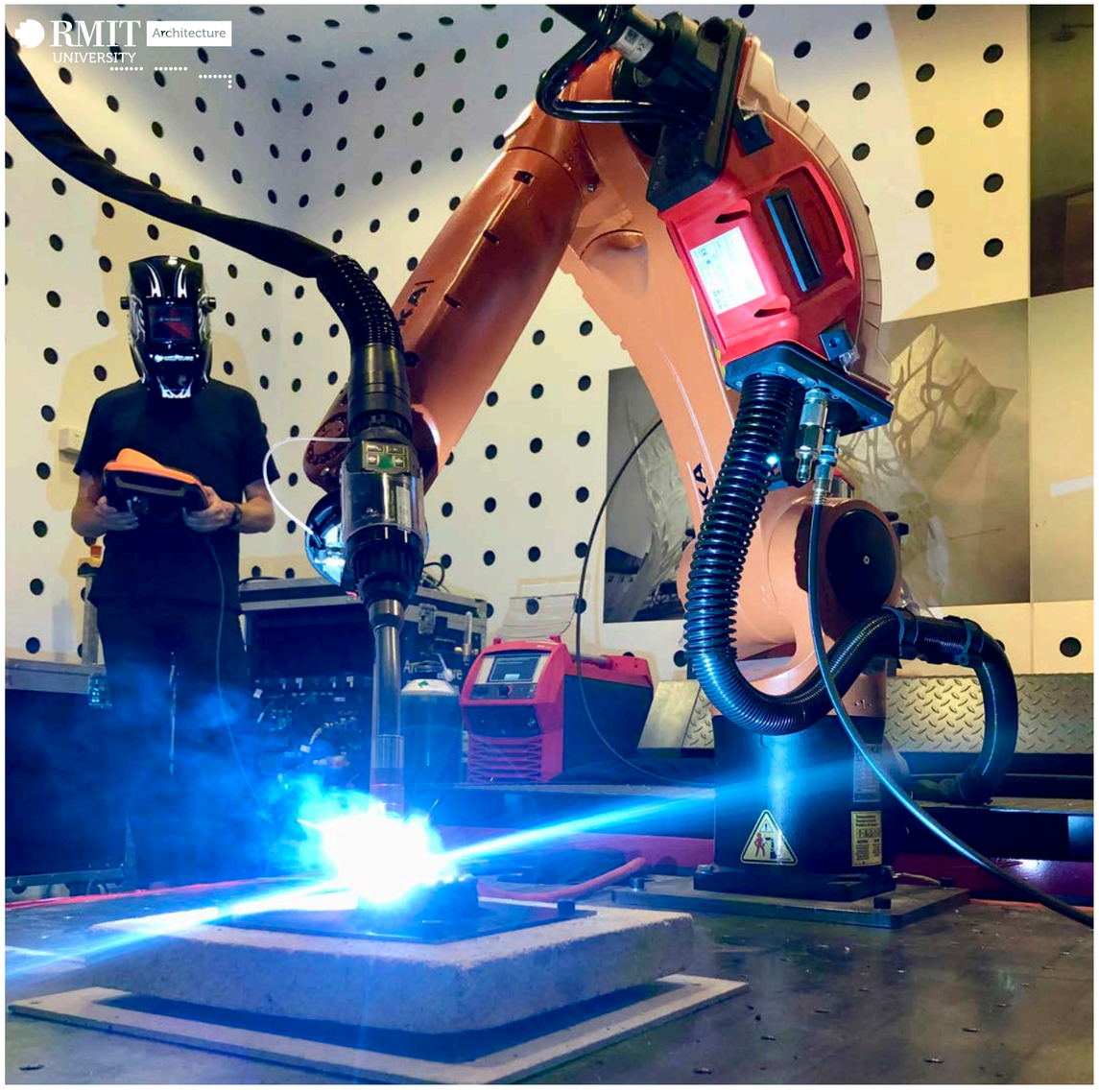
←
Development of large-scale 3D printing is a key technical innovation and area of research within the lab.

↑
The lab is an international leader in developing computational multi-agent algorithms for generative design and optimisation.

Our experimental design research is highly innovative and risk-taking. We speculate through design on the future of architectural form, material and tectonics. The work of the lab is at the forefront of algorithmic generative design and large-scale robotic polymer printing. Emerging research within the lab is extending these areas of expertise through machine learning, augmented reality, metal printing and printing of living biological structures. The research of the lab operates through design and its realisation within prototypes and demonstrator projects.

The research of the lab consists of a series of research trajectories focused on innovative processes. These trajectories are combined through collaborative design projects undertaken within the lab to demonstrate the potential of this research. The lab, which is part of the RMIT School of Architecture and Urban Design, is led by Associate Professor Roland Snooks who is internationally recognised as a leader in algorithmic architecture and robotic fabrication.

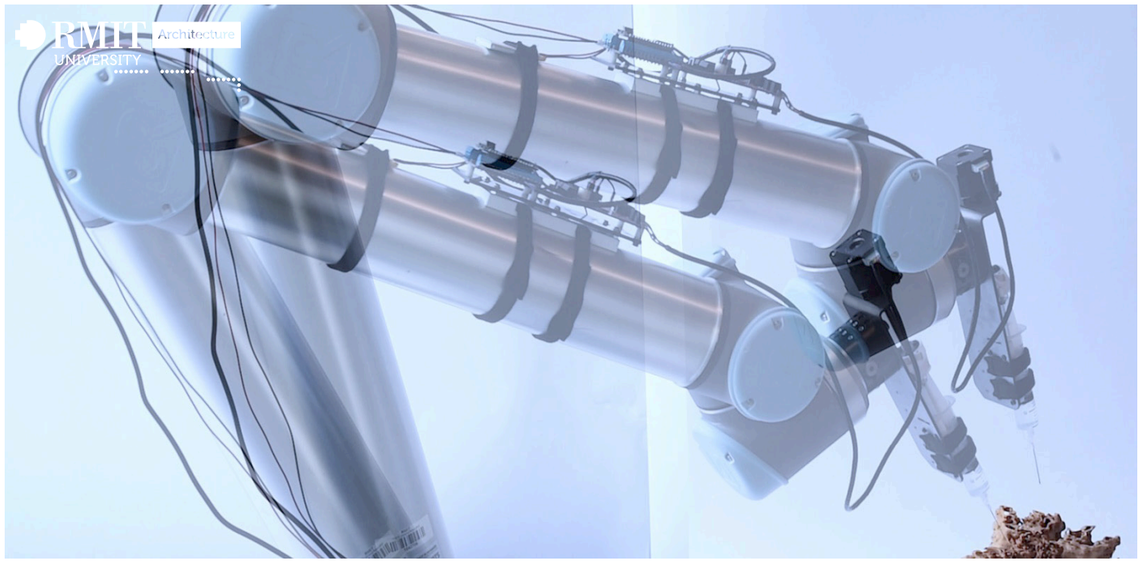
LAB OVERVIEW



Wire Arc Additive Manufacturing. A large-scale metal 3D Printing process in development at the Tectonic Formation Lab.

The lab develops innovative manufacturing and fabrication approaches through research and experimentation with industrial robotics. Over the last eight years the lab has developed a series of innovative robotic approaches and is a world leader in the development of large-scale polymer printing.

Our current research has a strong focus on additive manufacturing. We are testing a diverse range of emerging materials to be 3D printed and applied to the architectural field. These materials include recycled plastics, biodegradable composites, resins and metals.



Bio-Research: Computational robotic syringe injecting liquified mycelium into sacrificial biodegradable frameworks.

XL Polymer 3D Printing

The lab has been developing large-scale polymer 3D printing for architectural applications since 2014. This research explores techniques for robotic extrusion and the implications this has for design and has been tested through a series of demonstrator projects including components of permanent buildings.

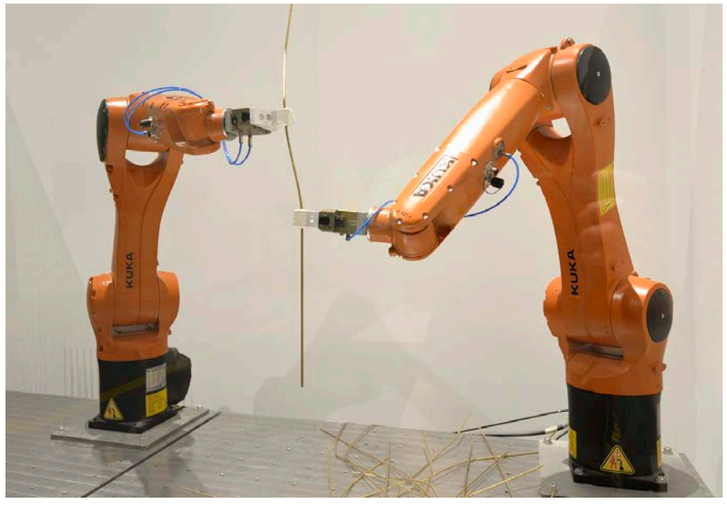
Large-scale Metal 3D Printing

The lab is developing a Wire Arc Additive Manufacturing (WAAM) approach for large-scale metal printing. WAAM operates through the deposition of metals using arc energy. This approach is fast and relatively inexpensive, making it the ideal approach to building scale metal printing.

Large-scale polymer 3D printing developed by the Tectonic Formation Lab.

Bio Printing

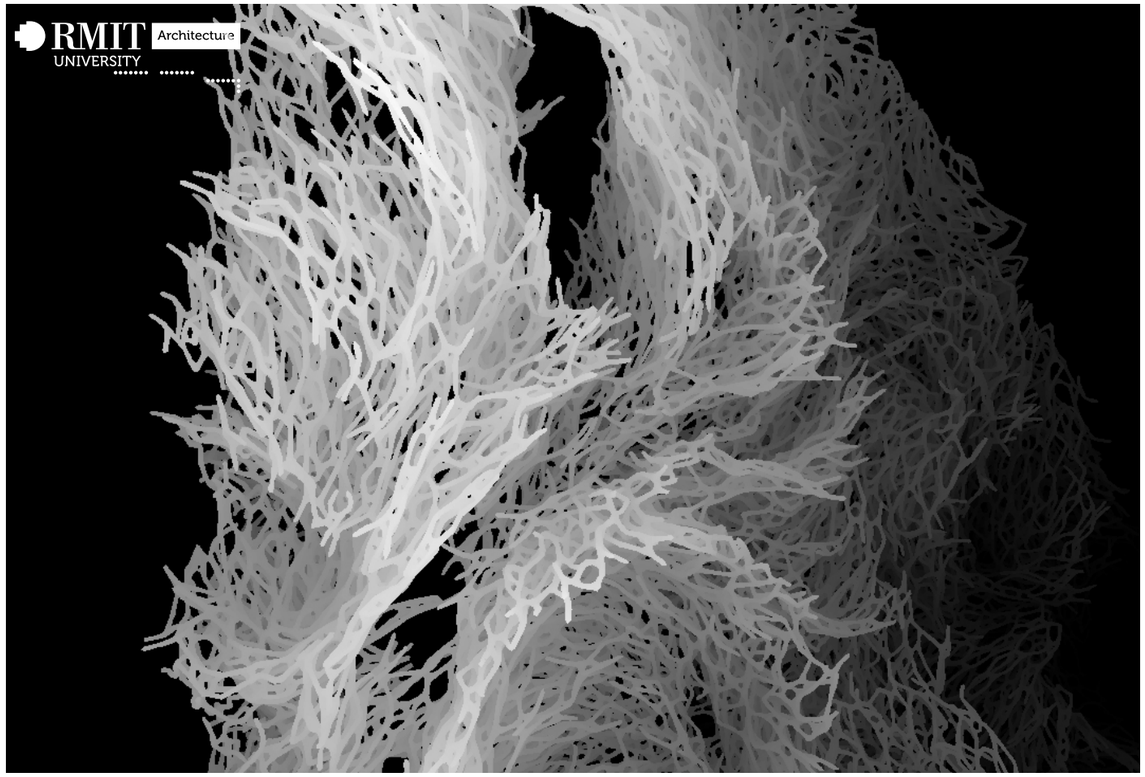
This research explores the design implications of constructing architecture from biological materials which are grown. In particular, the research is exploring robotic deposition/printing of mycelium and its interaction with 3D printed wood-bioplastic composite sacrificial formwork.



A robotic rod-bending fabrication process developed by the Tectonic Formation Lab.

Real-time robotics

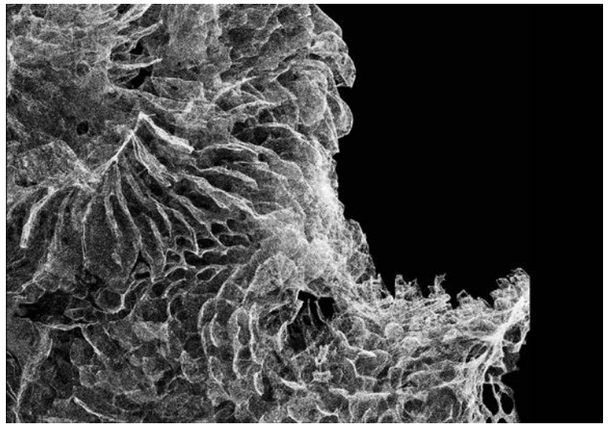
This research is developing robust real-time control systems and computer vision approaches to robotics. This is being explored as both a design generator as well as a technique for expanding the application of robotics to material fabrication.



The RMIT Architecture Tectonic Formation Lab is at the forefront of new computational design processes. We specialise in algorithmic approaches to both generative design and digital manufacturing.

The lab develops custom software based on our algorithmic design research, which is used within the design and resolution of complex projects. These innovations enable increased control of complexity and efficiencies through automation.

The two primary areas of experimental generative design within the lab explore multi-agent algorithms and artificial intelligence.



Multi-Agent Generative Design

Multi-agent algorithms model the interaction of populations of agents and the complex order that these interactions generate. Through a myriad of local interactions collective behavior emerges at the global scale. Multi-agent algorithms can be found within natural systems such as the flocking of birds, schooling of fish and the behavior of social insects. The intention of applying multi-agent algorithms to architectural design is to harness the non-linear capacity to solve complex problems and negotiate between numerous design imperatives.

↑
Nine Elms, 2018. The project explores high population algorithmic models to create a turbulent mass that blurs the definitions of line, surface and volume.

Machine Learning

Machine learning enables the training of algorithms in response to either existing data or defined training goals. The lab is exploring applications of machine learning both generative architectural design and the resolution of complex fabrication problems.

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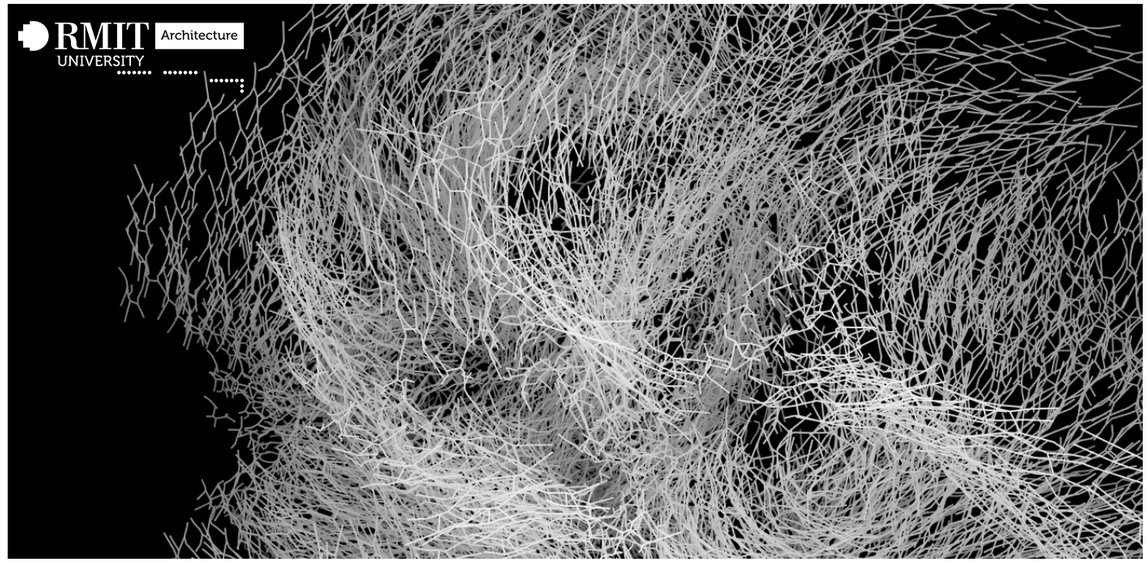
Painterly Forms 2, 2016. This experiment in intricate form was developed through the interaction of painterly operations and self-organising algorithms.

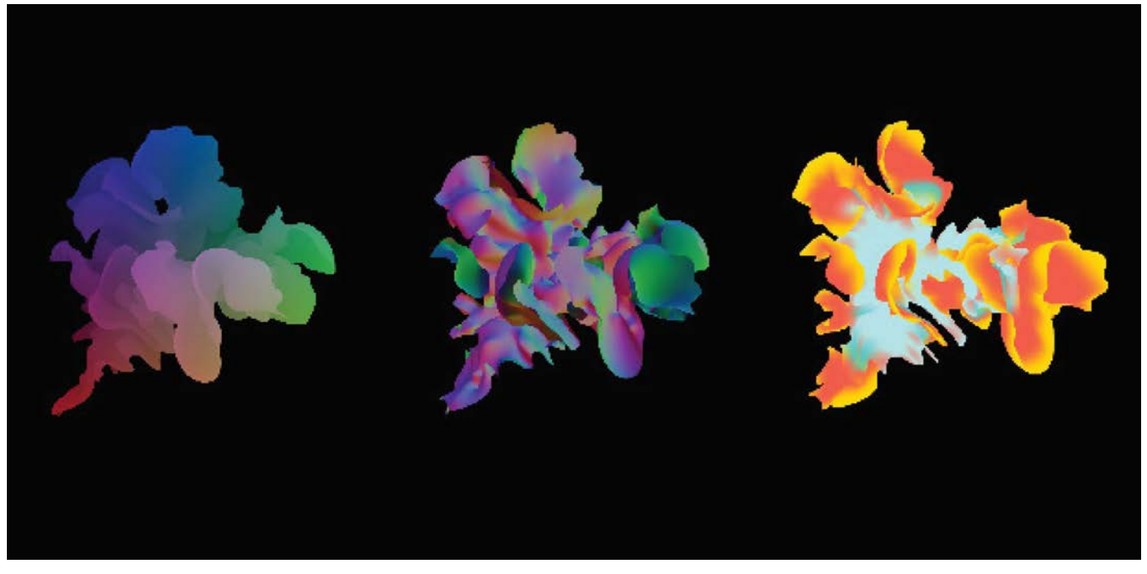


Behavioral Formation

A design methodology that draws on the logic of swarm intelligence and operates through multi-agent algorithms. This approach encodes design intent within computational agents that self-organise and create an emergent architectural intention.

This research has been continuously developed since 2002 and is the focus of Roland Snooks's algorithmic design research.

↑
Nine Elms, 2018. The project applies an agentBody algorithm developed by Roland Snooks.



Artificial Agency

This algorithmic design research project seeks to explore the operation of Machine Learning within venturous and highly speculative generative design processes and to examine its architectural implications.

The intention of the research is to explore the interaction of two ideologically opposed design approaches, multi-agent algorithmic processes and machine learning. This interaction and feedback has been examined to understand the opportunities afforded by their complementary logic.

↑
This multi-agent differential growth algorithm has been trained through a reinforcement learning algorithm to generate proto-architectural forms.

A key focus of the lab is the development of innovative tectonics through rethinking the relationship of building skin, structure, services and ornament. Through the application of emerging computational design and robotic fabrication approaches, we are attempting to re-imagine building construction systems and their architectural implications. Some of the important innovations we are developing in this area is exploring the reinforcement of 3D printed skins with structural material.

↑

Cast Bodies, 2019. The Cast Bodies prototypes explore the design and fabrication of intricate lattice structures through the application of 3D printed formwork strategies.

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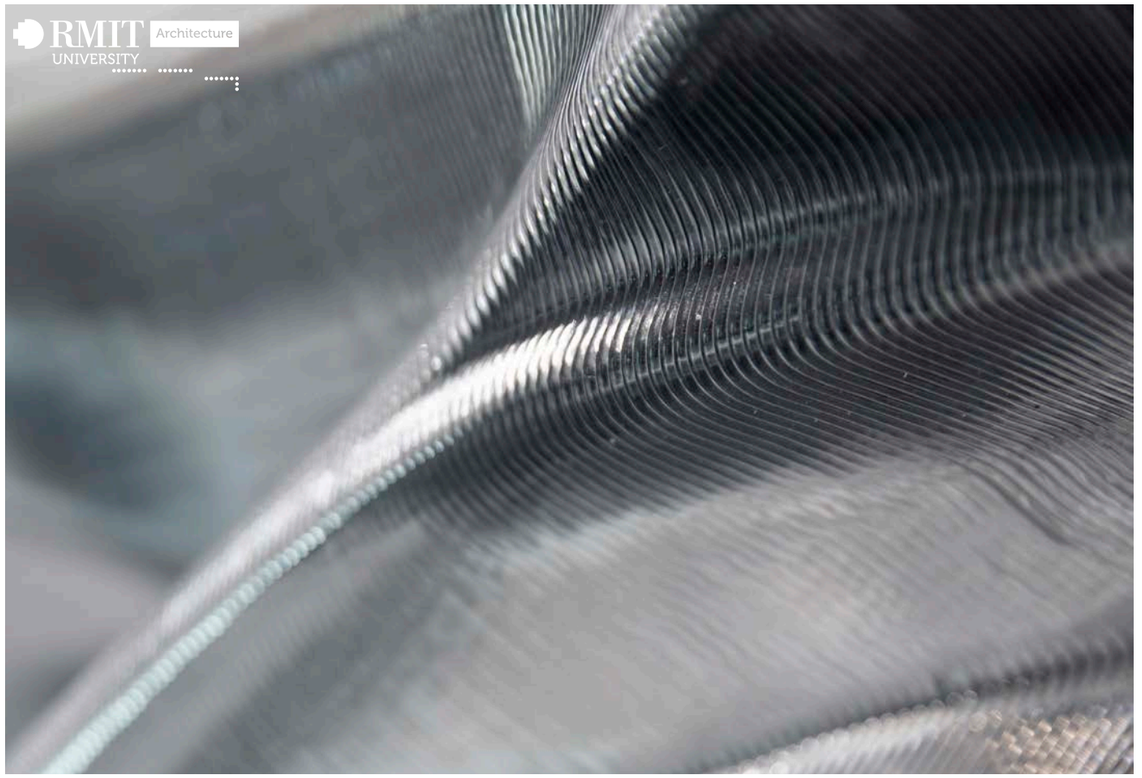
Nine Elms, 2018. The project explores high population algorithmic models to create a turbulent mass that blurs the definitions of line, surface and volume.



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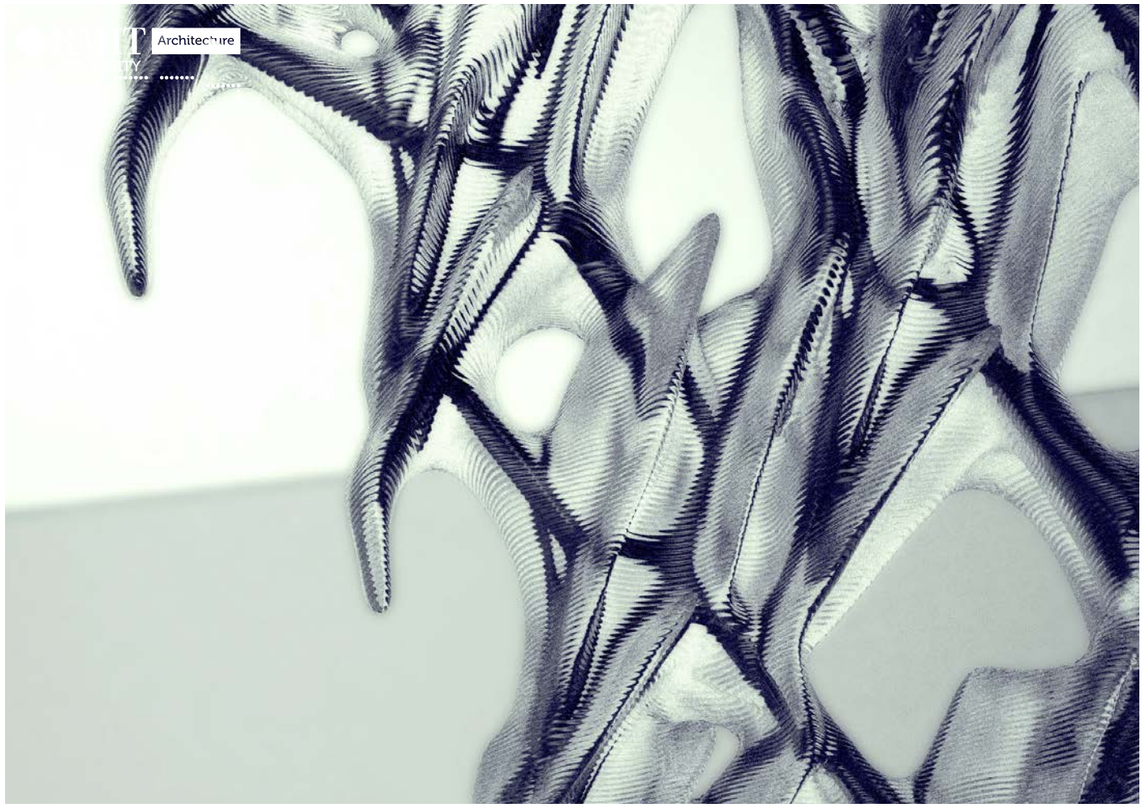
Unclear Cloud, NGV, 2021.

3D Printed Fiber-Composite Tectonics

This research explores the design of tectonic prototypes that compress surface and structure through the integration of carbon fibre composites and 3D printed polymer skins. This research expands on an ongoing agenda examining the architectural applications of large-scale FDM printing. The original contribution this research agenda makes is through the integration of carbon fibre and 3D polymer printing in order to create innovative tectonics, which compress surface and structure into an irreducible assemblage.

Polymer printed sacrificial formwork

This research explores large-scale polymer 3D printing of permanent, or sacrificial, formwork. The intention of this research is to create a hybrid of 3D printing and casting processes to leverage their different advantages. Through this research, we explore a series of 3D printed materials to act as either sacrificial or temporary formwork for fibre-reinforced cast concrete. As a result, we explore the design and fabrication of intricate lattice structures through the application of 3D printed formwork strategies.



MODELS OF PARTNERSHIP

We collaborate with industry through three primary models: multi-year research and development projects, technology transfer projects, and demonstrator projects.

Multi-Year Research Projects

Our major research projects include government funding in combination with industry funding. This funding is utilised for multi-year research and development projects that are focused on developing innovations with industry applicability.

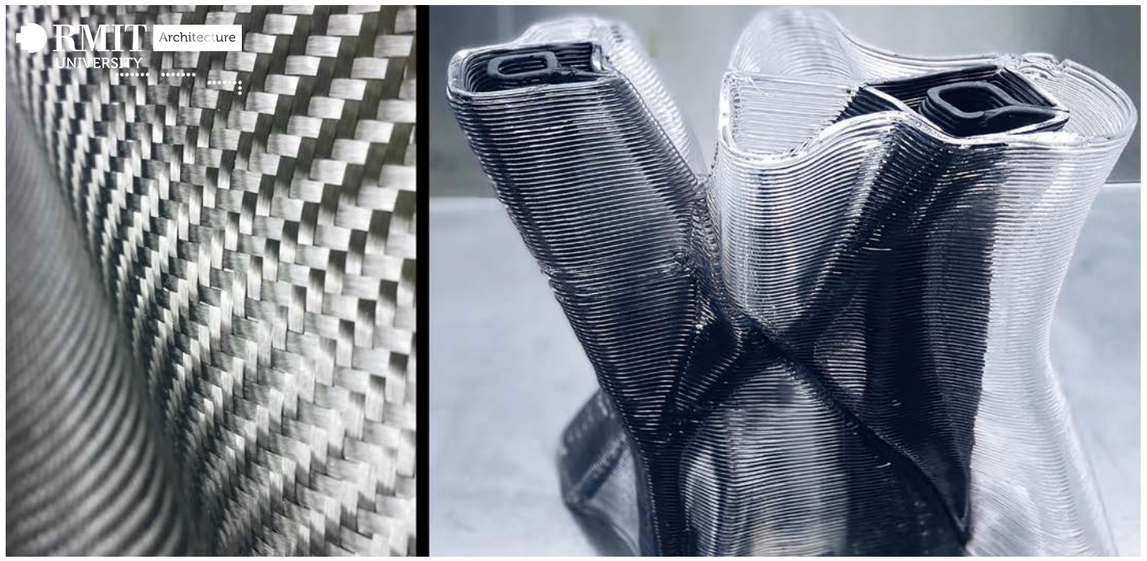
Technology Transfer Projects

By utilising the latest technological advancements in the computational and robotics industry, our team brings technical innovation to the point of commercialization which can be translated to industry partners.

Demonstrator Projects

Evident in our NGV and Shenzhen Biennale, we partner with institutions and companies to produce pilot projects, demonstrating the potential application of research. These projects are important to both create international impact as well as generating new markets for the demonstrated innovations.

HOW WE WORK WITH INDUSTRY PARTNERS

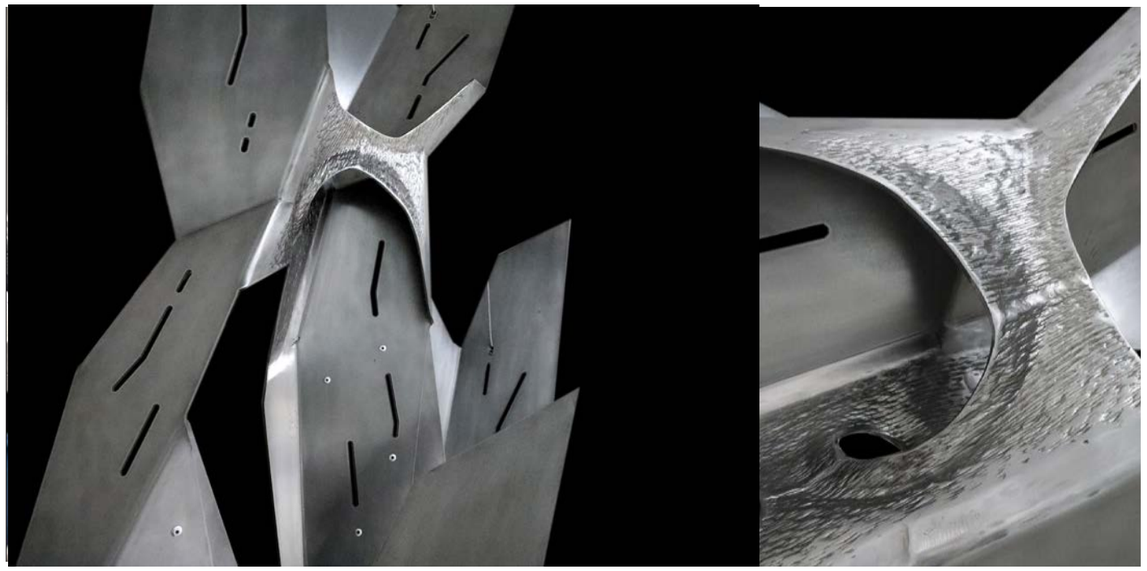


Studies in the integration of 3D printed polymer and carbon fibre. This research is part of the collaboration with Boeing Australia.

BOEING Alliance

The BOEING Alliance project is exploring the integration of 3D printing and carbon fibre placement. Through this exploration, the project demonstrates the potential of this manufacturing innovation for both the aerospace and building construction industries.

Experiments in the integration of carbon fibre and 3D polymer printing. Tectonic Formation Lab, 2021.



IMCRC Design Robotics

Design Robotics is a collaboration between RMIT, QUT and UAP which explores the integration of vision systems and robotics for advanced manufacturing..

The intention of this project is to develop strategies and processes that are transferable to Australian manufacturing companies to enable them to engage with automation and robotics. RMIT's role in this research project is focused on metal 3D printing through a Wire Arc Additive Manufacturing process.

WAAM metal 3D Printing. Tectonic Formation Lab, 2021.

HOW WE WORK WITH INDUSTRY PARTNERS

3D printed polymer walls of the SensiLab Studio. Tectonic Formation Lab 2017.

Collaboration is a key to the operation of the RMIT Architecture Tectonic Formation Lab, across disciplines, institutions and industries.

While grounded within architectural design, the work of the lab crosses into disciplines including aerospace, advanced manufacturing, structural engineering, art, construction, biology and computer science.

The lab has strong, active collaborations with numerous other schools within RMIT, most notably Aerospace, Engineering and Computer Science. The lab also collaborates with international institutional partners in Europe, Asia and the US.

Engagement with industry is key to creating impact and accessing expertise. The lab is primarily funded through industry partnerships and has research contracts of over a million dollars from industry to RMIT University. These primarily take the form of multi-year industry-funded research projects but also include externally funded pilot, or demonstrator, projects.

While a significant portion of the funding comes from industry and government schemes, a vital component of the research is undertaken by RMIT-supported PhD candidates. This is critical to the innovative nature of the lab through developing blue-sky speculative design research, that is at an experimental stage, prior to engaging with industry.

COLLABORATION + INDUSTRY PARTNERS

KEY PARTNERSHIPS

RMIT CROSS-DISCIPLINARY COLLABORATORS:

RMIT Centre for Innovative Structures and Materials
Director: Prof. Mike Xie

RMIT Aerospace
Prof. Stuart Bateman

RMIT Computer Science
Assoc. Prof. Fabio Zambetta

RMIT Advanced Manufacturing Precinct
Prof. Milan Brandt

CROSS-INSTITUTIONAL COLLABORATORS:

SensiLab, Monash University, Australia
Prof. Jon McCormack

Queensland University of Technology, Australia
Dr Jared Donovan

Tongji University, China
Prof. Philip Yuan

ETH Zurich, Switzerland
Prof. Benjamin Dillenburger

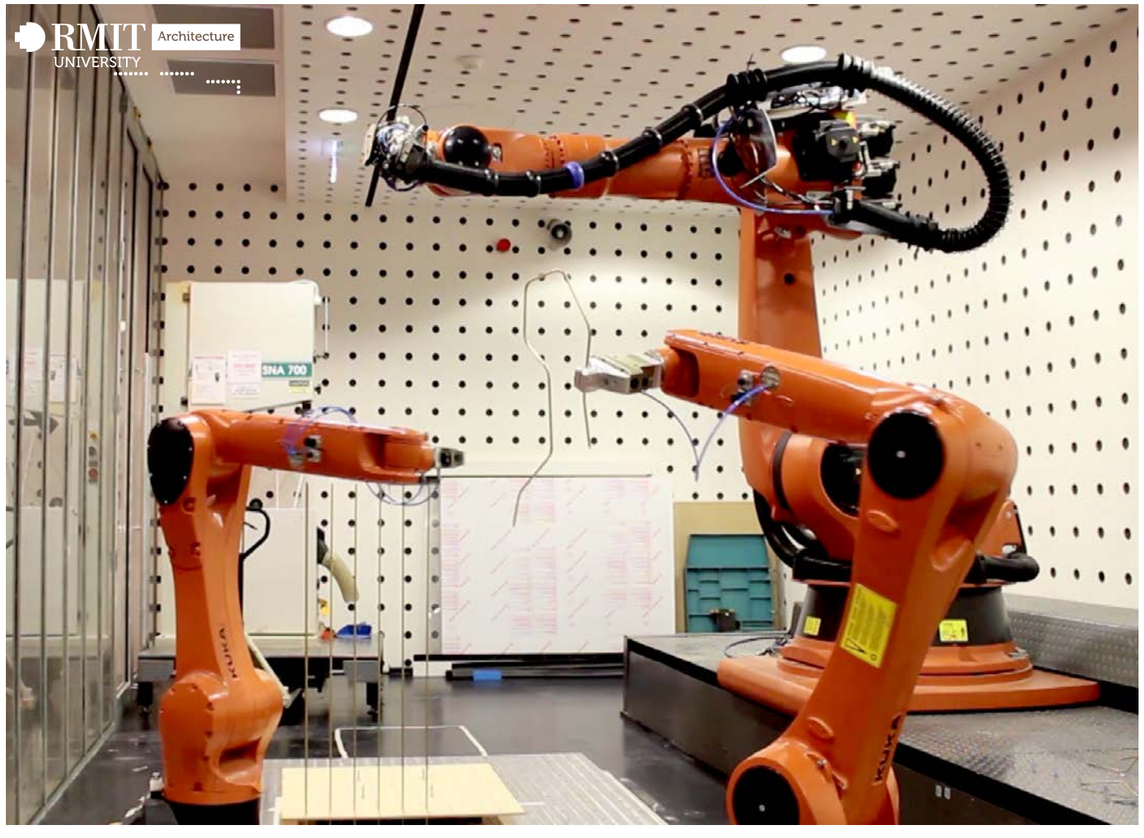
University of Pennsylvania, USA
Robert Stuart-Smith

INDUSTRY PARTNERS:

Boeing, USA/Australia

UAP Company, USA/China/Australia

National Gallery of Victoria, Australia



RMIT Architecture Industrial Robotic Fabrication Cell.

Research Space

The RMIT Architecture Tectonic Formation Lab is housed with the RMIT Design Hub as part of RMIT Architecture discipline within the School of Architecture and Urban Design. The lab space consists of workstations, meeting areas, a maker space and an exhibition space. These spaces facilitate the collaborative and vibrant research culture of the lab.

Robotic Facilities

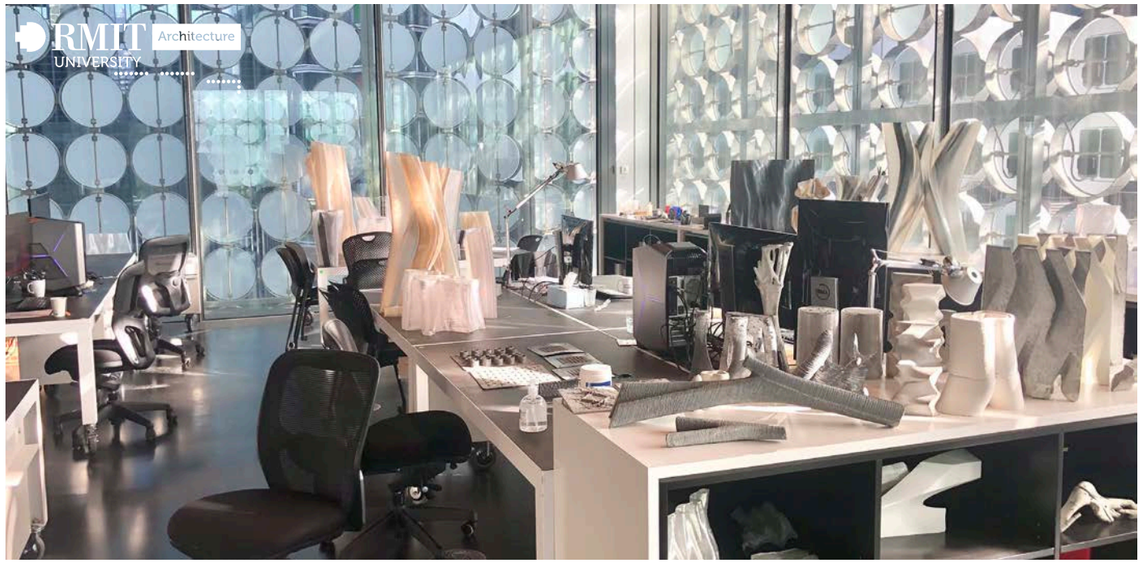
RMIT University has the leading architectural robotics facility in Australia. This robotic facility consists of nine industrial robots ranging in scale up to the Kuka KR150 (2700mm reach + 5000mm linear axis, 150kg payload.) This robot is most commonly utilised throughout our research outputs for large-scale 3D printing.

Our smaller Kuka Agilus robots are commonly used for robotic welding and metal printing. For real-time robotics, vision systems and experimental techniques we utilise the Universal Robots (UR10's).

Robotic Tools

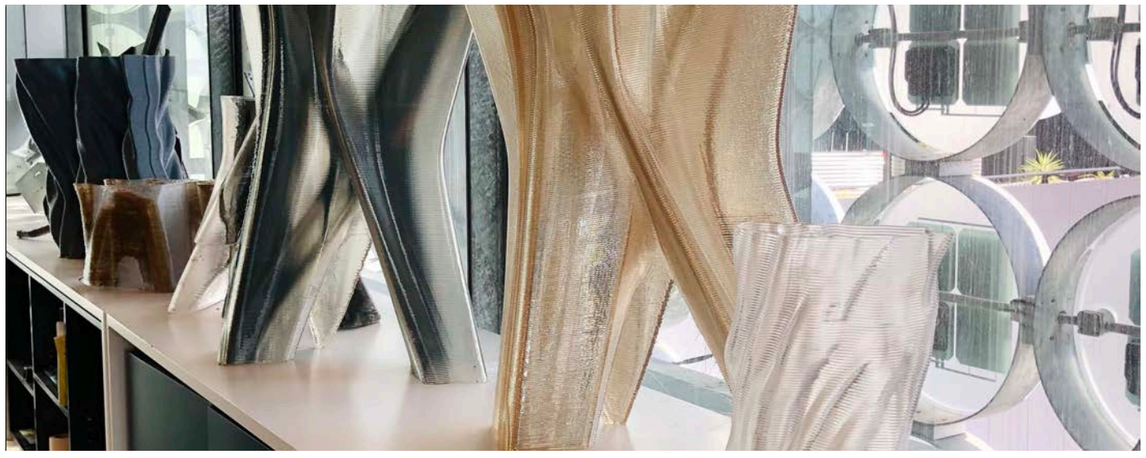
The robots are equipped with a series of end-effectors:

- Polymer and clay extruder's for 3D printing,
- MIG/CMT welders for wire arc additive manufacturing,
- Hot wire and blade tools for foam carving,
- Grippers for pick and place operations,
- Incremental sheet forming tools
- Fiber-placement tools,
- Experimental tools developed by the lab.



Research Lab

Tectonic Formation Lab work space



Research Lab

Tectonic Formation Lab work space

RESEARCH SPACE + ROBOTIC FACILITIES

Roland Snooks

DIRECTOR

Roland Snooks

Professor Roland Snooks directs the Tectonic Formation Lab. Snooks's design research explores behavioral processes of formation that draw from the logic of swarm intelligence and the operation of multi-agent algorithms.

Snooks has taught widely in the United States including at Columbia University, University of Pennsylvania, SCI-Arc, and the Pratt Institute. He received a PhD from RMIT and a Master in Advanced Architectural Design from Columbia University, where he studied on a Fulbright scholarship.

In 2004 Snooks co-founded the experimental architectural practice Kokkugia, with the intention of exploring the limits of algorithmic formation and its architectural potential.

Snooks's work has been published and exhibited widely and acquired for the permanent collections of institutions including the FRAC and Centre Pompidou.

Team

The Tectonic Formation Lab consists of researchers with a diverse set of expertise. The highly collaborative nature of the research enables researchers to focus on specific topics and develop in-depth expertise.

This expertise includes specialisation in algorithmic design, machine learning, robotic fabrication, 3D printing, structural optimisation, fibre composites and biological growth. While diverse, these areas of research and expertise are explored through architectural design.

The researchers are a combination of Research Fellows, PhD candidates, Research Assistants and associated faculty from RMIT Architecture.

Marc Gibson
Digital Lead

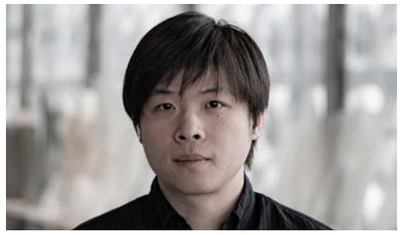
Charlie Boman
PhD Candidate

Jackson Bi
Associate Lecturer

Natalie Ailma
PhD Alumni

TEAM

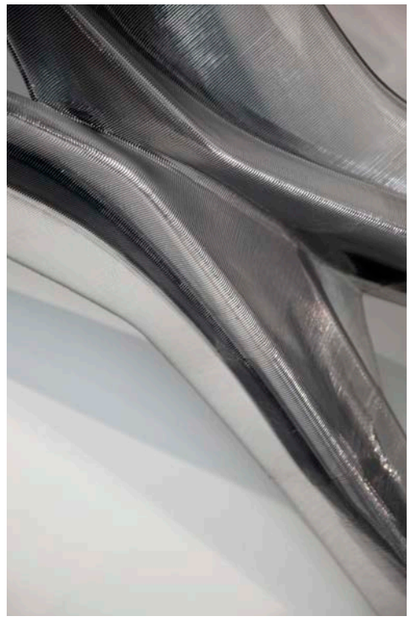
Alan Kim
PhD Candidate



Nic Bao
Senior Lecturer

Hesam Mohammad
PhD Alumni

Dasong Wang
PhD Alumni



Unclear Cloud

National Gallery of Victoria

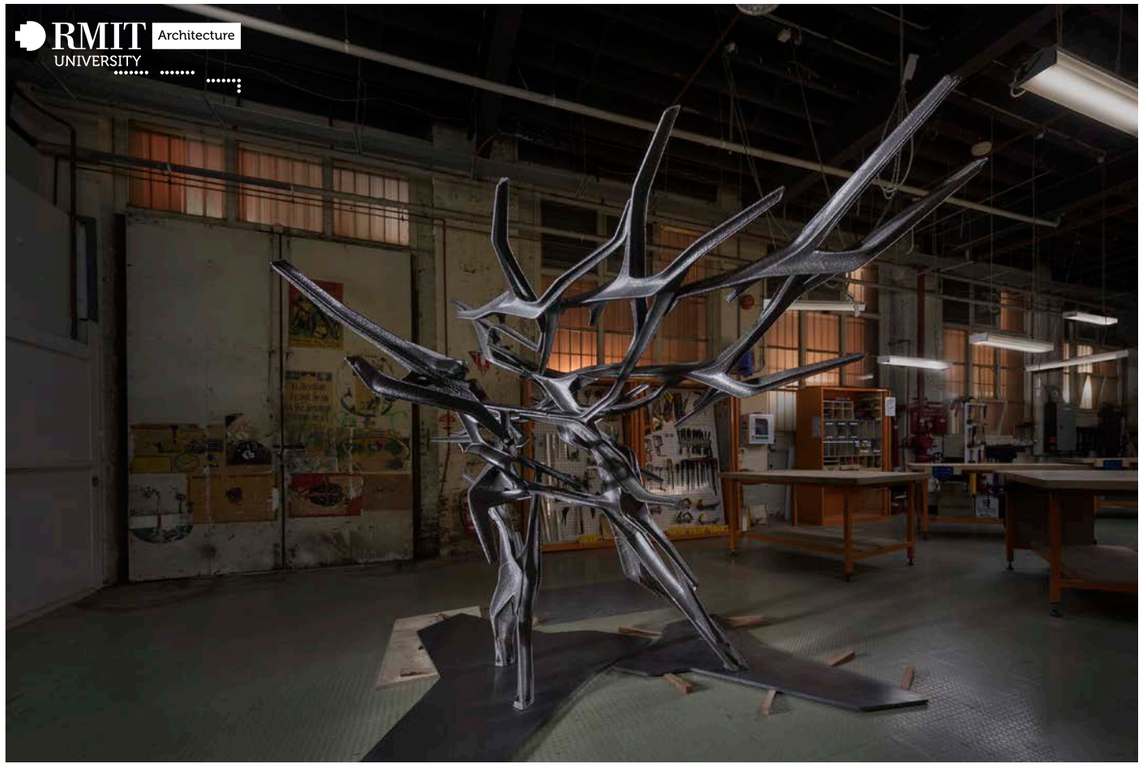
Melbourne, Australia

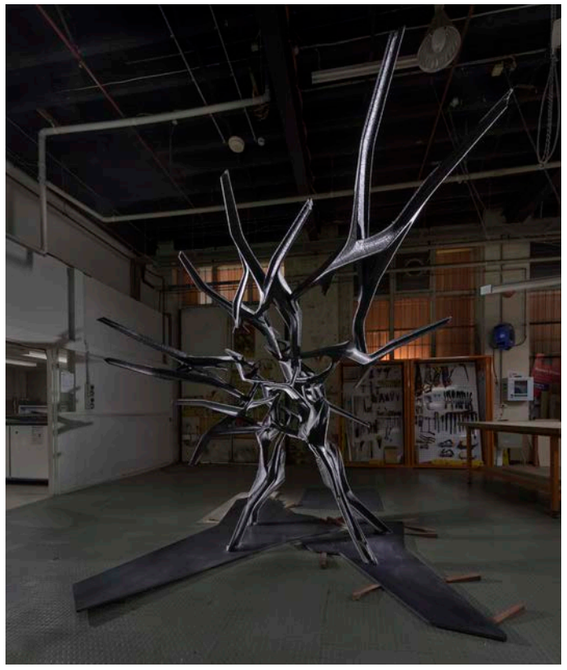
2021

This 3D printed project explores the tectonic compression of surface and structure into an irreducible assemblage. The 3D printed plastic skin acts as a sacrificial formwork for the infusion of a carbon fibre structural skeleton, supported by a metal printed (WAAM) transfer structure. The installation at the NGV is accompanied by a sound artwork by Philip Samartzis which uses transducers to transform the structure into a spatial speaker for the multi-channel soundscape.

↑

Unclear Cloud





Remnants of a Future Architecture

Melbourne Art Fair

Melbourne, Australia

2022

Remnants of a Future Architecture is a series of architectural artifacts that speculate on the tectonics and design implications of large-scale metal printing. The WAAM metal printing technique deployed in the project has been developed by the RMIT Architecture Tectonic Formation Lab over the past 4 years.

↑

Remnant 1

Floe

National Gallery of Victoria
Melbourne Australia
2018

Floe draws on the atmospheric effects of the Antarctic landscape to create a theatrical architectural installation designed in response to a sound work by Philip Samartzis. The project explores the architectural implications of algorithmic design through pre-fabricated, robotic 3D fabrication. The translucent skin of the tower is composed of seventy unique overlapping semi-clear polymer panels, which were developed in response to a modest budget ($125k design & construction) for a non-standard speculative pavilion.

↑
Floe

Cloud Affects

Shenzhen Biennale

2019

Cloud Affects is an architectural and sonic installation developed in collaboration between Associate Professor Roland Snooks (RMIT Architecture) and Associate Professor Philip Samartzis (RMIT Art). The project, currently being exhibited at the Shenzhen Biennale, explores the design implications of polymer skins reinforced with carbon fibre lattices. The architectural installation was 3D printed at RMIT through a robotic technique to create highly intricate and complex forms.

↑
Cloud Affects

SensiLab Studio

Monash University
Melbourne, Australia

2017

The SensiLab Studio is a robotically 3D printed polymer meeting room located at Monash University in Melbourne. The intricate geometry of the wall is algorithmically generated with a complex corrugated form to create structural rigidity.

This is a pioneering project in the application of 3D printed translucent polymers to permanent building structures. The polymer panels have passed the relevant fire and building codes within Australia.

SensiLab Studio

Composite Wing

RMIT Design Hub
Melbourne Australia
2014

The composite fibre installation compresses surface, structure and ornament into one intricate and irreducible assemblage. The complexity of the project is made possible through the development of robotic fabrication techniques including the extrusion of the fine-scale surface articulation.

The surface gains its strength through the location of the articulation that operate as structural beams within the surface. This strategy enables the surface to remain only a few millimeters thick while spanning and cantilevering considerable distances.

Composite Wing

Composite Swarm

RMIT Design Hub
2013

The Composite Swarm installation is an architectural

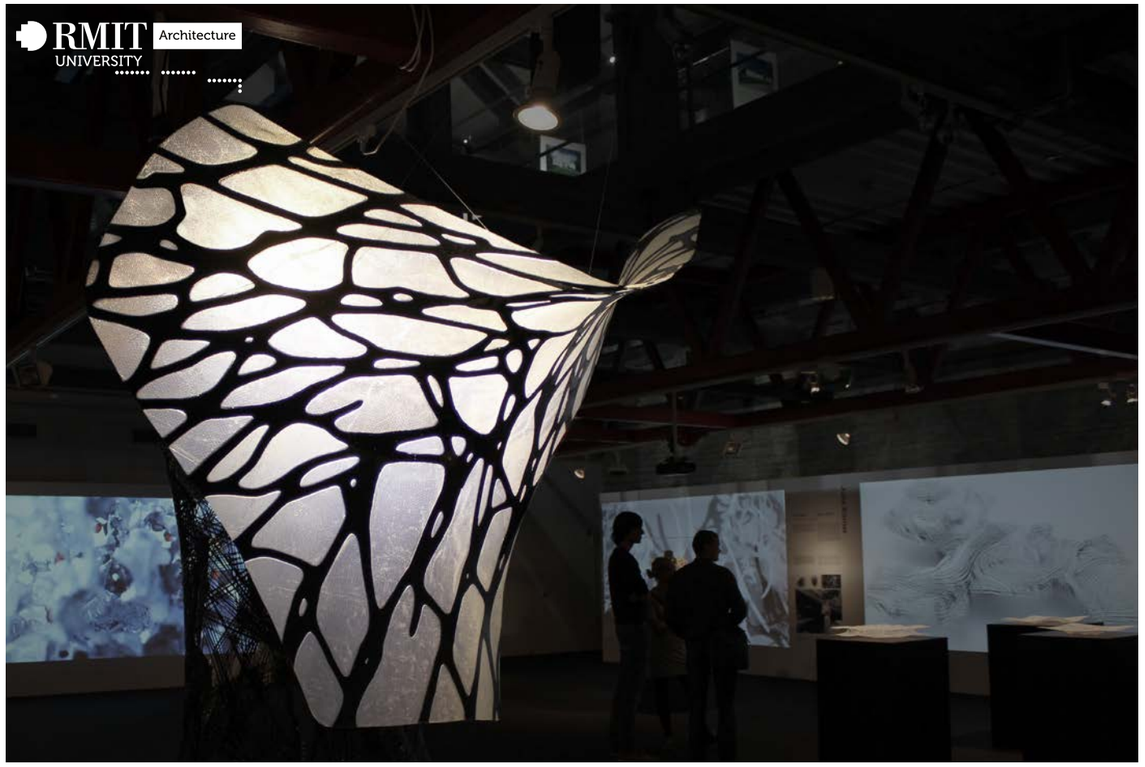
prototype exploring the relationship of robotic fabrication, composite materials and algorithmic design.

The complexity of the form and the excess of ornament

make the prototype structurally efficient and minimize the amount of material used.

The prototype is 2.5 meters tall, with a surface thickness of

↑
Composite Swarm



Composite Skeleton

Taliinn Architecture Biennale
2015

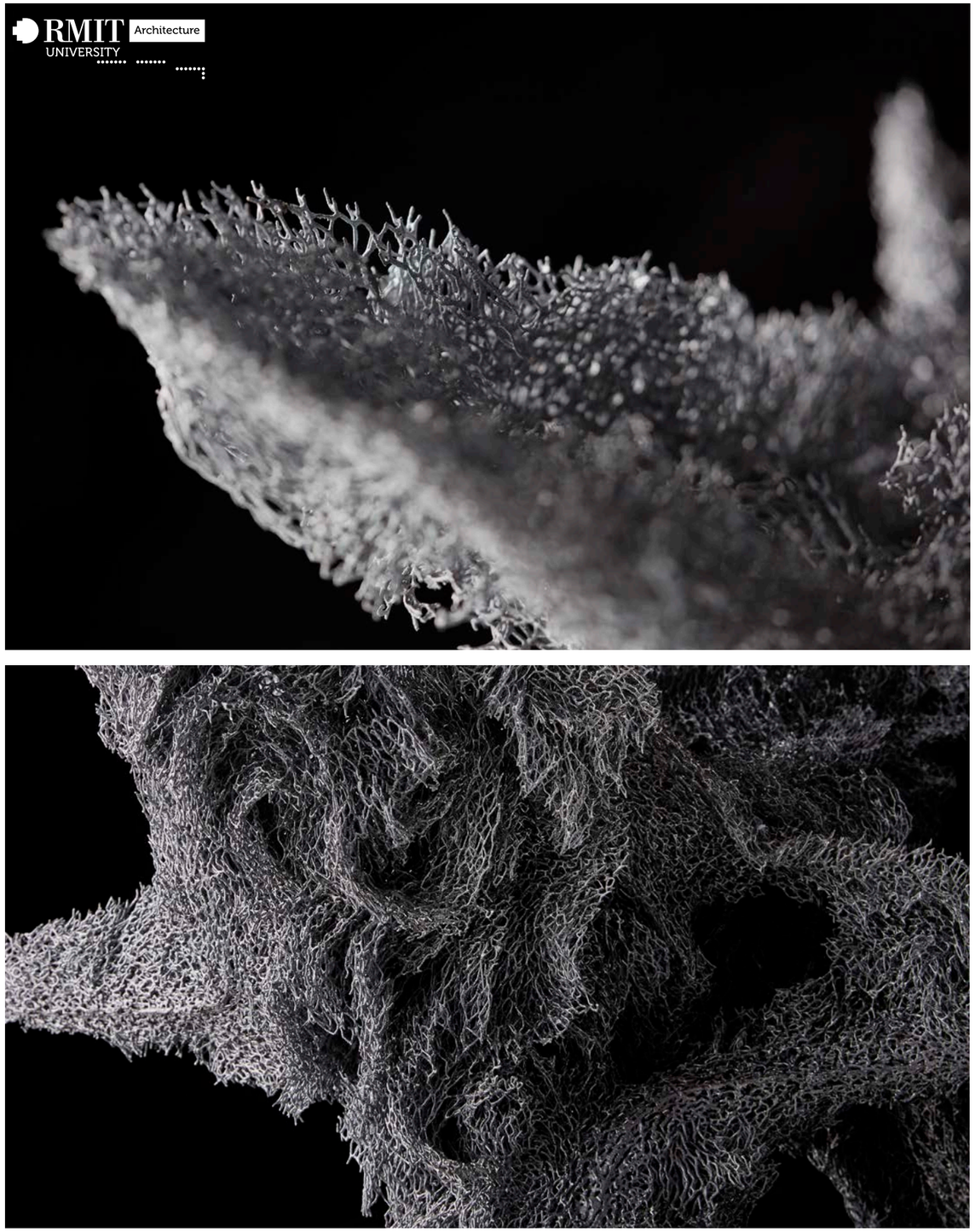
Composite Skeleton is a composite fibre prototype

developed for the Talliin Architecture Biennale and exhibited in Estonia.

The translucent skin of the prototype is 0.25mm thick and

provides the shear strength of the project, while the black skeleton is 2mm thick.

↑
Composite Skeleton



Nine Elms

Centre Pompidou,

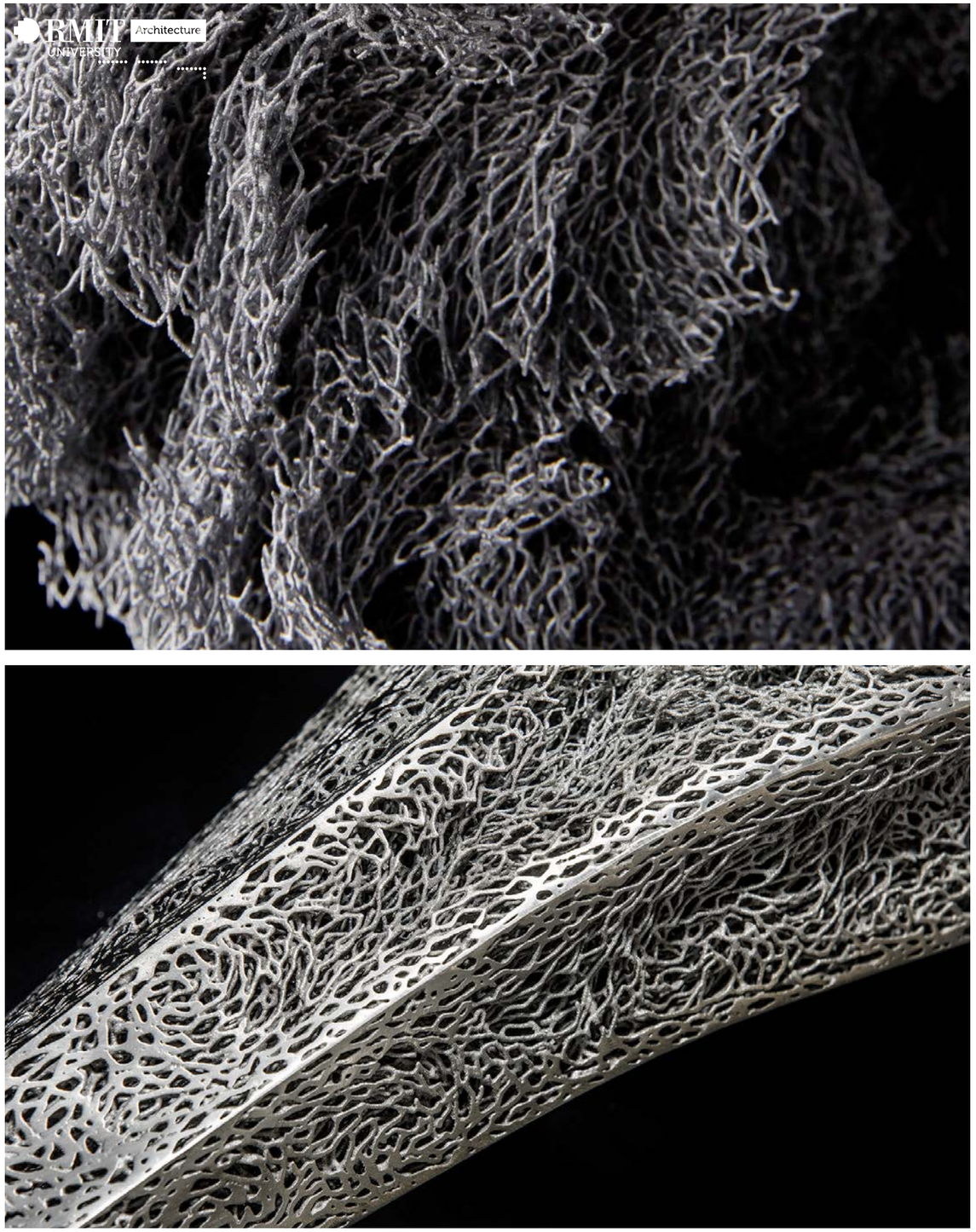
Paris, France
2018

This project was commissioned and acquired by the Centre Pompidou for its permanent collection. Originally it was exhibited in the Coder Le Monde exhibition in 2018.

The project explores high population algorithmic models to create a turbulent mass that blurs the definitions of line,

surface and volume. Our multi-agent algorithmic processes are included in the exhibition, which charts the pioneering development of algorithmic work in art and design.

Nine Elms



RMIT Mace

RMIT Design Hub
Melbourne Australia
2015

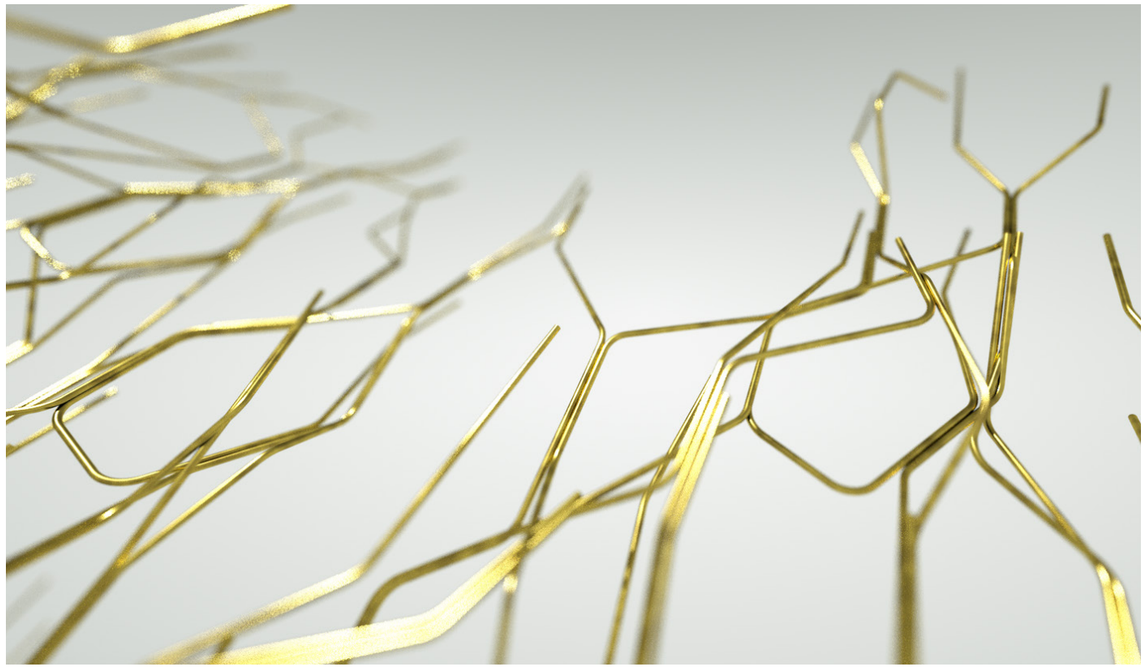
The new RMIT Mace combines multi-agent algorithmic design research and 3D printing technology to create a new symbol for the university. The project draws upon the intricate and ornamental characteristics of historical mace and reinterprets these through computational design processes.

This project is designed through a multi agent algorithm

to produce an accretion of intricate mass, rather than predefined form.

The mace was fabricated through a laser sintering process

RMIT Mace



Brass Swarm

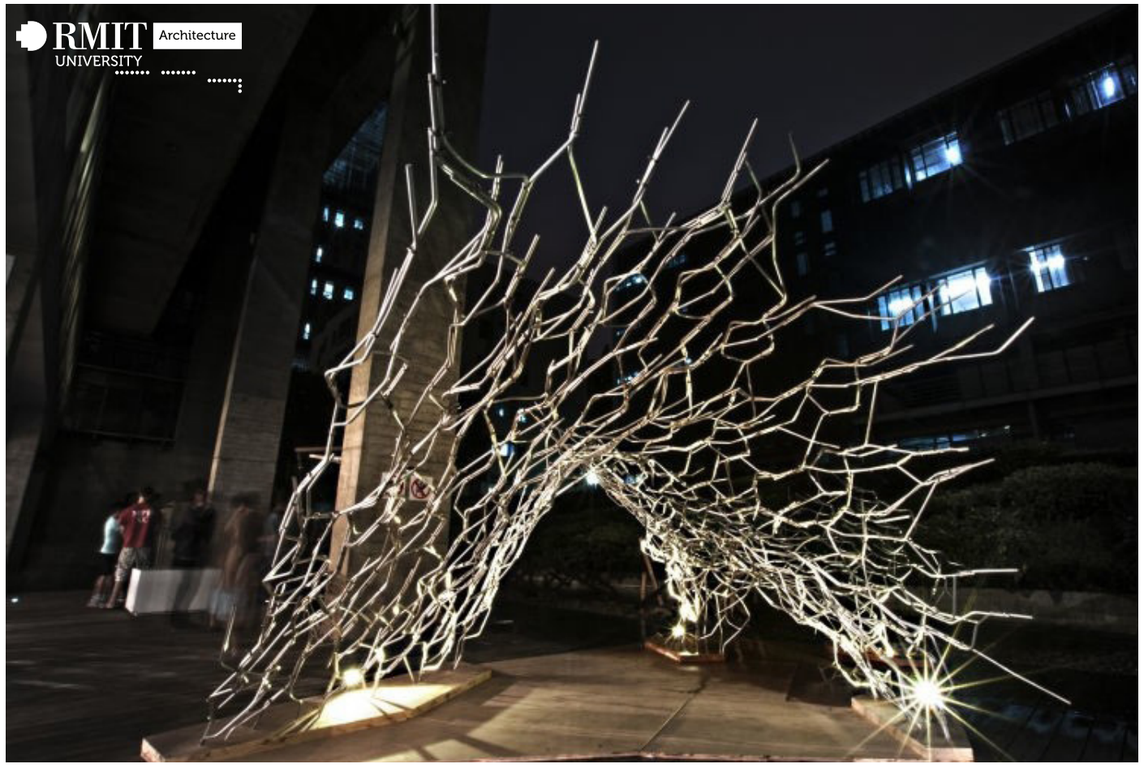
Shanghai Biennale,

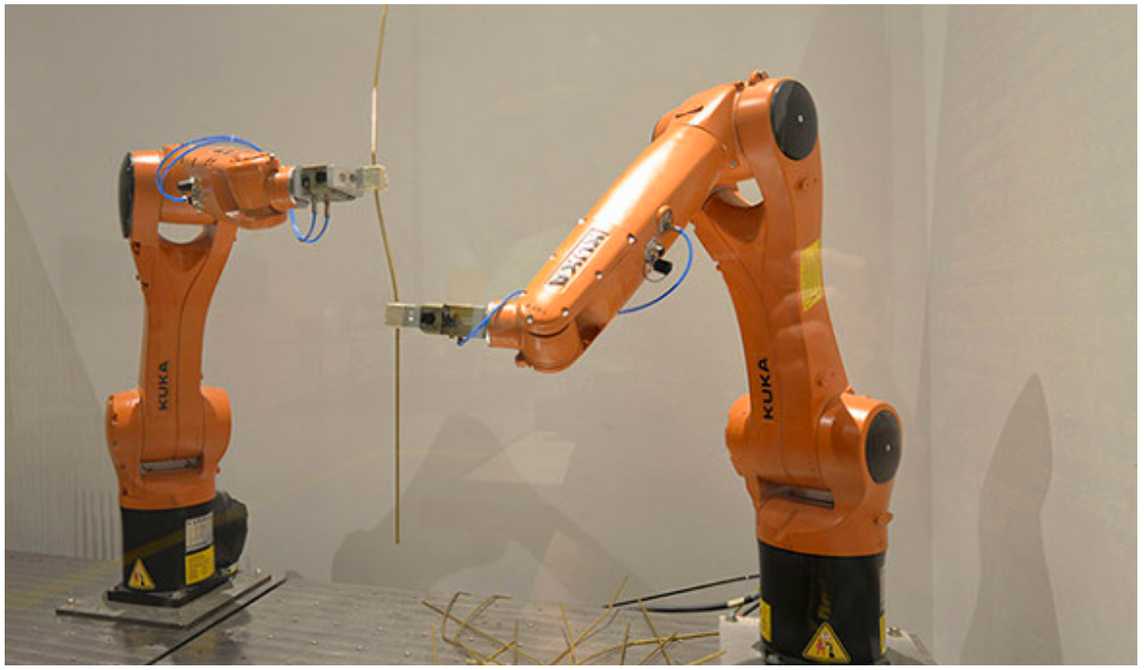
Shanghai, China
2015

Brass Swarm is an experimental prototype developed through self-organisational algorithmic design processes and robotic fabrication. The project explores spatial self-organisation, emergent tectonics and the relationship between robotic and algorithmic behavior.

A multi-agent algorithmic strategy for spatial self organisation was developed, from which topological surfaces emerge. This manifold swarm strategy self-organises clouds of agents into coherent, continuous surfaces, and complex spatial division.

↑
Brass Swarm





DADA Pavilion

Tongji University

Shanghai, China
2015

Using advanced algorithmic strategies and robotic fabrication, this research involved creating intricate, continuous surfaces using metal rods that are bent and joined together to create a cohesive three-dimensional form.This pavilion was an attempt to scale up the logic first developed in the Brass Swarm project.

The project is generated through an agentBody algorithm and fabricated through the interaction of two industrial robots.

The generative algorithm developed for this project negotiates between the complex design behavior and more realistic fabrication process.

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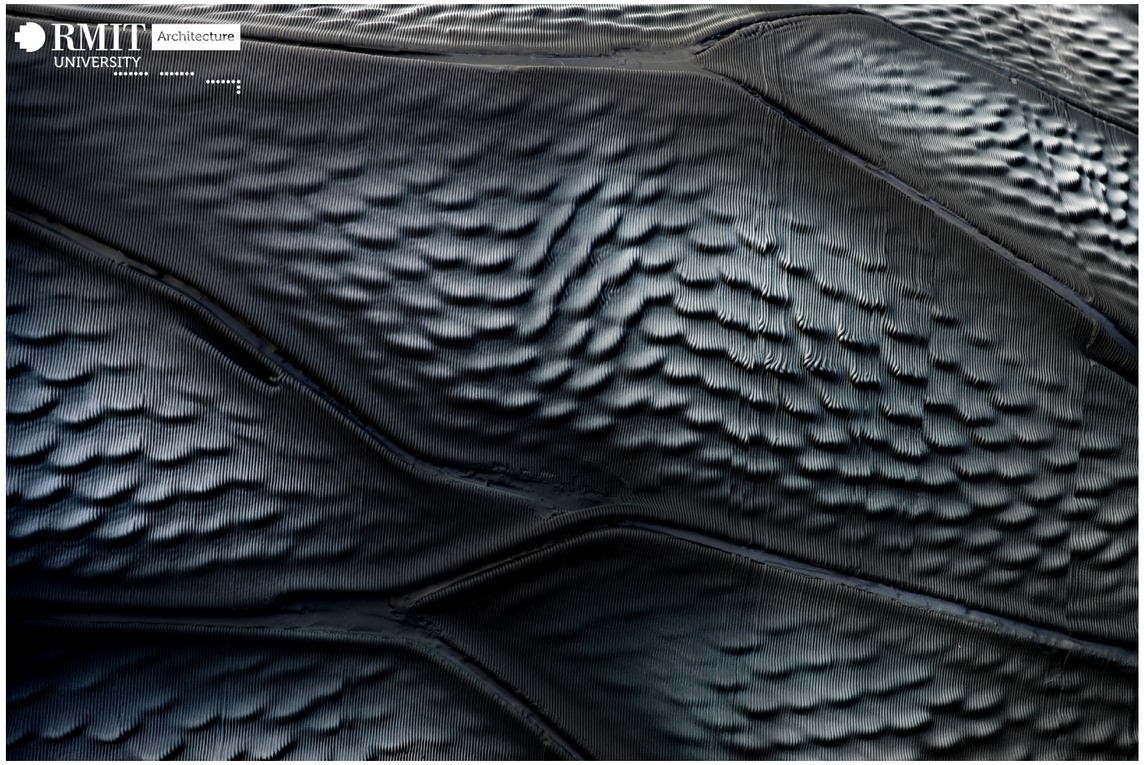
DADA Pavilion



Composite BioForms

NGV Design Week

2021

Bio Forms explores experimental strategies, such as growing architecture through the interaction of 3D printed skins and mycelium. Printed Tectonics' is an exhibition exploring the positive environmental impact of building-scale 3D printing and its implications for architectural design. The projects speculate on the architectural applications of 3D printed recycled and biodegradable materials and minimising waste through metal additive manufacturing. This research considers the lifecycle of material, waste and industrial supply chains.

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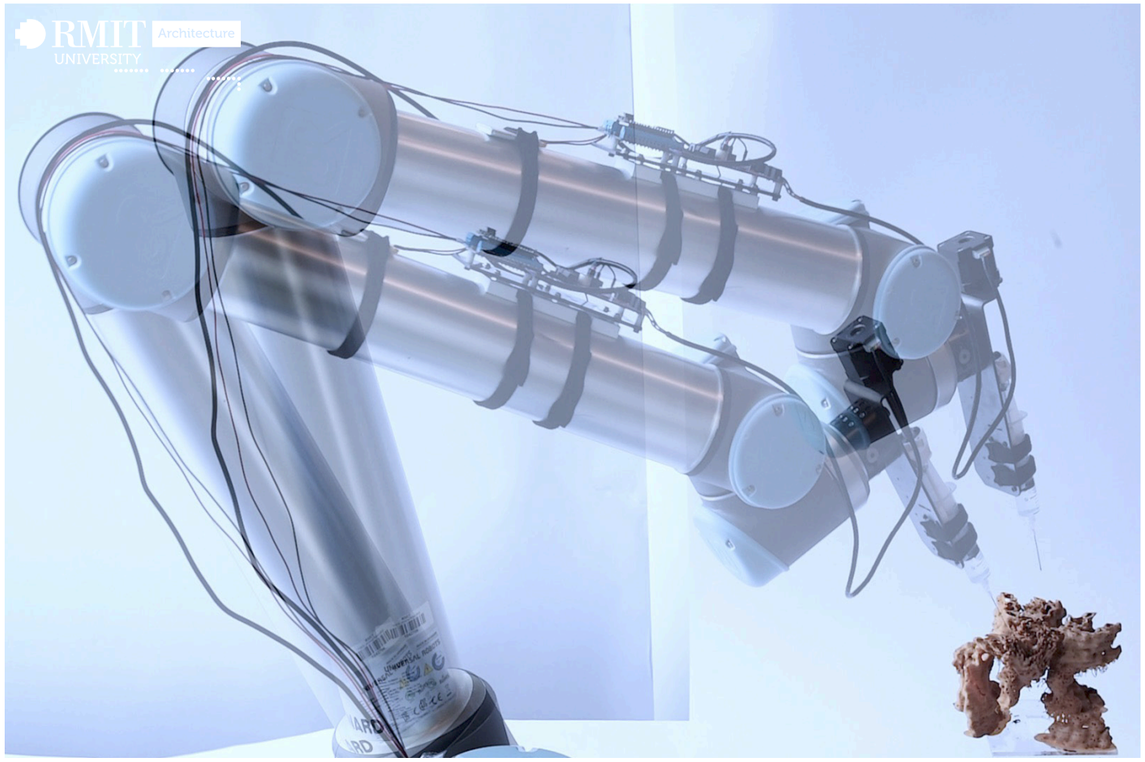
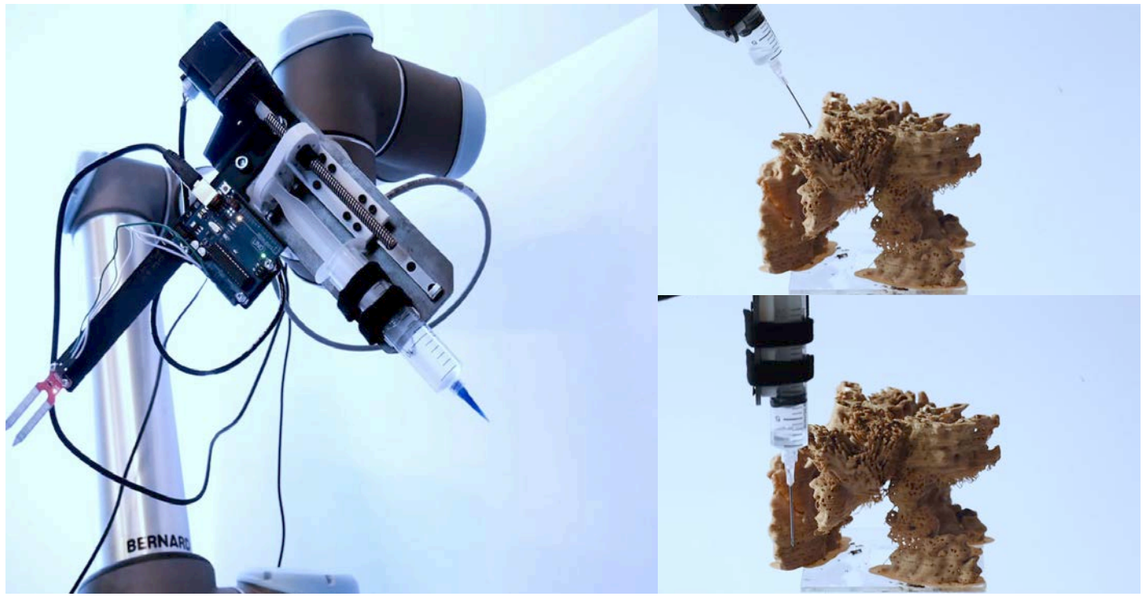
Composite BioForms





Bio Scaffold

RMIT Design Hub
Melbourne Australia
2019

BioScaffolds posits a robotic strategy for creating a symbiosis of biological and computational agencies through the interaction of mycelium and 3D printed scaffolds. Through this relationship, we explore live adaptive feedback systems in which natural processes can work in collaboration with digital fabrication technologies. By establishing a cybernetic intelligence between plant and machine, we explore a series of design tectonics which emerge from a co-creation between human, machine and natural intelligences. As a result, we showcase live fabrication systems where mycelium is robotically infused into a series of sacrificial frameworks.

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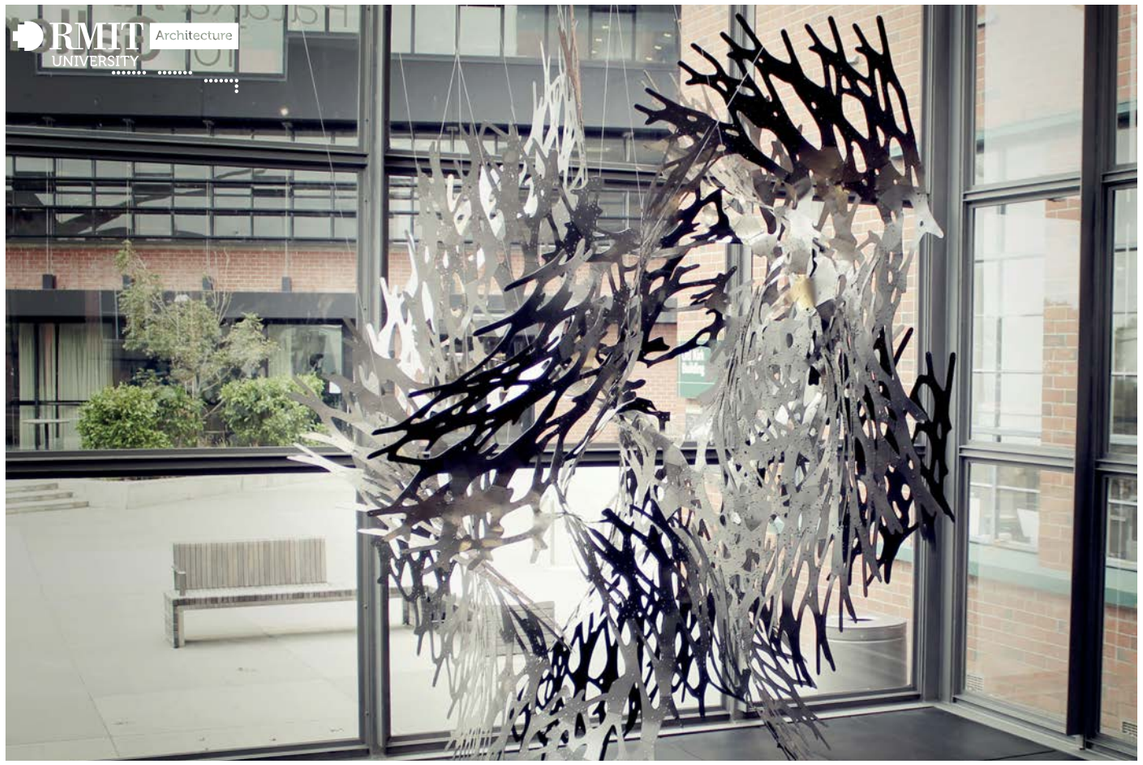
Bio Scaffold



Laminar Bodies

Wellington, installation

2015

The Laminar Bodies installation was exhibited at the Adam Gallery in Wellington in 2015. The project explores the translation of algorithmically generated complex geometry into surfaces fabricated from laser cut steel sheet. The complex curvature of the form is achieved through the lamination of relatively small sheet steel components that assemble to form the highly intricate computational geometry. This local flatness of the geometry limits the structural depth and necessitates creating structural strength through surface curvature.

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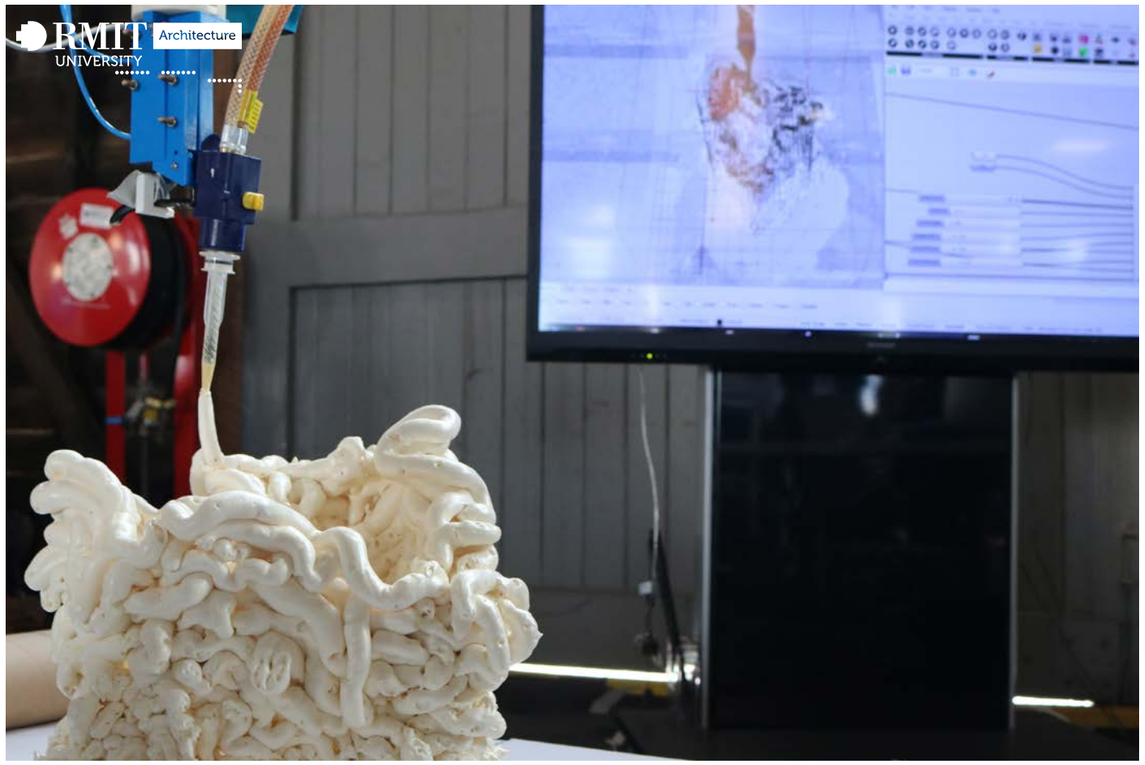
Laminar Bodies



Stigmergic Accretions

RobArch

2016

This workshop explored the compression of design and fabrication into a single process. The intention of the process is to create a feedback between material agency and computational agency, where real-time robotics and vision systems become the medium of interaction.

Rather than generation geometry as a predetermined form, this research explores the highly volatile characteristics of form as it created in real time.

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Stigmergic Accretions

RMIT UNIVERSITY Architecture

TECTONIC FORMATION LAB

RMIT Architecture | Tectonic Formation Lab
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