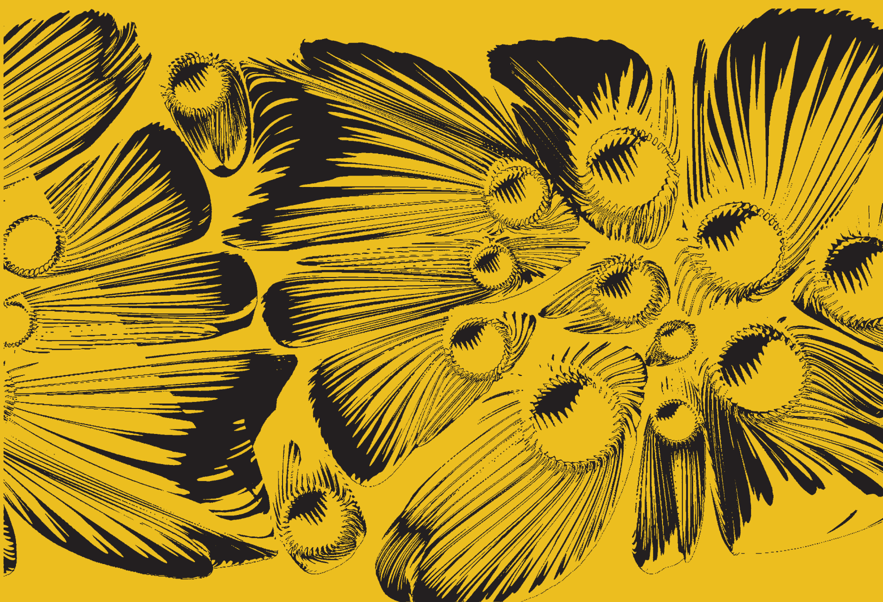
Bartlett Design Research Folios

# ProtoRobotic FOAMing



by mam, Grymsdyke Farm and REX|LAB

# Project Details

| | |
|---|---|
| Practices: | mam, Grymsdyke Farm, REX\|LAB |
| Designers: | Marjan Colletti and Marcos Cruz, Guan Lee |
| | Colletti and Cruz contributed equally to the research on the rigid foam panels through their practice mam architects, and Lee was co-designer and fabricator of the final outcomes of this research. |
| | Colletti conducted the research on wet foam through REX\|LAB, at the University of Innsbruck's Institute for Experimental Architecture. He is the founder and director of REX\|LAB. |
| Title: | ProtoRobotic FOAMing |
| Output type: | Design |
| Main venues: | ArchiLAB, FRAC Centre (Fonds Régional d'Art Contemporain de la région Centre), Orléans (Sep 2013 – Feb 2014); Smartgeometry, London (Apr 2013) |
| Budget: | approx. £150,000 |
| Funding: | UCL Bartlett School of Architecture; Bundesministerium für Wissenschaft und Forschung; University of Innsbruck, Institute for Experimental Architecture; Grymsdyke Farm; Smartgeometry |
| Software developer of Robotic FOAMing: | Thibault Schwartz |
| Research assistants: | Richard Beckett, Jonas Brazys, Vasileos Chlorokostas, Hubert Ducroux, David Edwards, Pavlos Fereos, Muhammad Hissaan, Jessie Lee, Emu Masuyama, Keith McDonald, Olivia Pearson, Cullum Perry, Awaiz Randhawa, Alexandrina Rizova, Sébastien Tabourin, Camille Tenart, Johan Voordouw, Tze-Chun Wei (rigid foam panels); Georg Grasser, Stephan Hechenberger, Kadri Tamre, Allison Weiler (wet foam) |
| Fabrication: | Digital Manufacturing Centre, Bartlett; Grymsdyke Farm; REX\|LAB, Innsbruck |

# Statement about the Research Content and Process

## Description

**ProtoRobotic FOAMing is a research project that examines morphological change and energy efficiency resulting from manipulating foam through digital fabrication. A series of experimental prototypes aim to change the use of foam from an ordinary cavity wall insulation material to a more visible material composing entire building envelopes.**

## Questions

1. **How can digital and computational design techniques, CNC technologies and industrial robots aid the fabrication of complex building structures through the use of foam?**
2. **How can these techniques counter the increasing costs of bespoke architectural fabrication and assembly, while developing novel aesthetics?**
3. **How can they reinterpret guidelines on environmental design and engineering (especially Passive House guidelines) in an innovative and sustainable way?**

**1 *(previous page)* Seventy-three individually milled hard foam elements hosting Objet 3D printed algae vessels, resting on a 2m × 4m milled foam frame with complex geometry (Algae-Cellunoi by marcosandmarjan and Guan Lee, ArchiLAB 2013)**

**Methods**

**The project developed through two stages of prototyping, using rigid blown foam boards and fast curing soft polyurethane foam tubes, mixed with cement and stretched by robotic arms:**

1. **Digital computational input (modelling, simulating, scripting, scanning) and output by CNC fabrication and 1:1 assembly;**
2. **Digital computational operational control and simulation of machinery (milling machine, 3D printers, robots scripting).**

**Dissemination**

**Iterations of the work have been exhibited in Orléans (2013–2014); Tallinn, Innsbruck, Vienna, Prague (2013); Graz (2012); Tel Aviv (2011); and London (2010–2013). The research has been presented in six keynotes and over 40 invited talks, including in: Melbourne, Orléans, Cyprus, Prague, Ottawa, Bolzano (2013); Munich, Stuttgart, Graz (2012); Vienna, Tel Aviv, Moscow (2011); Gothenburg, Guatemala, Venice (2010); Los Angeles, Copenhagen, Lausanne (2009); Lund and Oslo (2008).**

# Statement of Significance

**Selected as one of the commissions for the 2013 ArchiLAB exhibition at the FRAC Centre (Fonds Régional d’Art Contemporain de la région Centre). Colletti received a grant of approx. £100,000 from the Bundesministerium für Wissenschaft und Forschung and University of Innsbruck to establish the REX|LAB laboratory.**

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# Introduction

ProtoRobotic FOAMing examines morphological change and speculative energy design resulting from digital manipulation of insulation materials, such as cavity wall foam. It develops simple approaches to design and construction through using the earliest forms of robotic fabrication methods. The research aims to begin to bridge the gaps in scale, price and expertise between relatively simply achievable rapid-prototype models and 1:1 architectural designs that are fabricated using CNC methods. It also examines how insulation foam can be manipulated towards more efficient building envelops and better environmental control of spaces with less energy consumption (in line with Passive House regulations) while developing a novel aesthetic language.

Initial research focused on applying widely available milling fabrication technologies with clear mechanical limitations (e.g. bed size, z-axis constraints) and geometric limitations (e.g. undercuts, volume constraints) to rigid panels of foam, testing them for fitness and appropriateness. Algae-Cellunoi, installed at the 2013 ArchiLAB exhibition Naturalizing Architecture, synthesises these technologies and earlier experiments into one piece.

Following this work with rigid panels, the research progressed to experimentation with wet foam, using a MultiMove set-up with three movable ABB IRB2600 robots. The open layout, combined with the flexibility of the total sum of an 18-axis industrial robot (as compared to the three axes of a generic CNC milling machine) is believed to overcome many mechanical and geometric constraints. [fig. 1 & 2]

**2**
**Robotically formed stretched foam bifurcation detail (Robotic FOAMing by REX | LAB and workshop participants, Smartgeometry 2013)**

# Aims and Objectives

The project aims to externalise foam insulation and use foam as a pliable design tool in CNC fabrication.
It increases the formal potential to implement ornamentation, geometry and texture. It also considers the retrofitting possibilities of the advanced design and use of foam in existing buildings with low-energy performance.

The project treats foam as a structural material and uses it both in its rigid form, as a board, and in its soft, wet condition. It aims to explore whether foam is capable of materialising larger 1:1 prototypes with the geometric and spatial complexity of smaller 3D rapid-prototype models. Foam is a material with great potential and relatively low costs: it can be soft or stiff, it can be shaped, it is light and easily transportable, and it has good insulation properties. Overall, the project aims to develop:

1. Ways of addressing the rising technical, structural, material and financial difficulties through advances in CNC methods and robotic fabrication;
2. Ways for responding to Passive House energy regulations through the digital manipulation of foam which can contribute to novel applications of insulation in both new and existing buildings;
3. Methods for generating complex morphologies that simulate biological growth.

# Questions

### How can digital and computational design techniques, CNC technologies and industrial robots aid the fabrication of complex building structures through the use of foam?

In the last three decades computing power and availability, and the flexibility and adaptability of computer-aided design (CAD) software packages, have rapidly increased, making computers more than indispensable tools to the discipline of architecture. These have broadened architecture's formal vocabulary (Lynn 1999) and been supported by speculative theories of architecture. More recently, designers who seek to translate these digital approaches into more 'organic' or 'emergent' forms of design consider these to be 'post-digital' or 'neo-materialist' architectures (Colletti 2013).

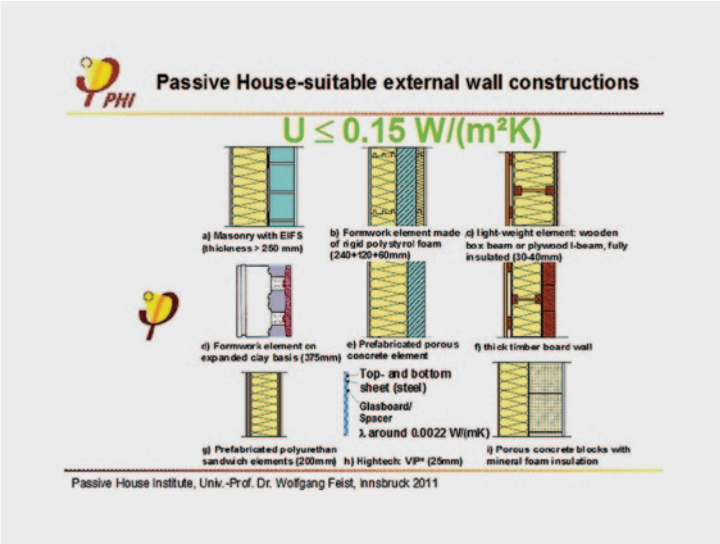
### How can these techniques counter the increasing costs of bespoke architectural fabrication and assembly, while developing novel aesthetics?

The use of digital fabrication methods in the building industry can have a considerable influence on costs, with potential savings on shipping and personnel, and lower energy consumption. Innovative fabrication methods and assembly protocols go hand in hand with research into a material's production, behaviour, properties and capacities. The project investigates how digital and computational design techniques and fabrication technologies, in combination with novel uses of foam, can achieve new material aesthetics and optimal performance (e.g. structure, insulation). [fig. 5 – 7]

### How can they reinterpret guidelines on environmental design and engineering (especially Passive House guidelines) in an innovative and sustainable way?

ProtoRobotic FOAMing aims to provide an alternative to some of the EU guidelines on insulation, as defined by the Passive House regulations (www.passivhaus.org.uk, www.passivhaustrust.org.uk), which recommend thick layers of insulation. These thick surfaces can be indoors or outdoors. This opens up new possibilities for architects to design more three-dimensionally by manipulating the thickness of foam. [fig. 3 & 4]

Furthermore, the methods of ProtoRobotic FOAMing can be developed for the retrofitting of low-performance buildings with specifically designed foam surfaces. With the implementation of thermal imaging and 3D scanning, precise bespoke façades can be designed to accurately fit existing conditions.

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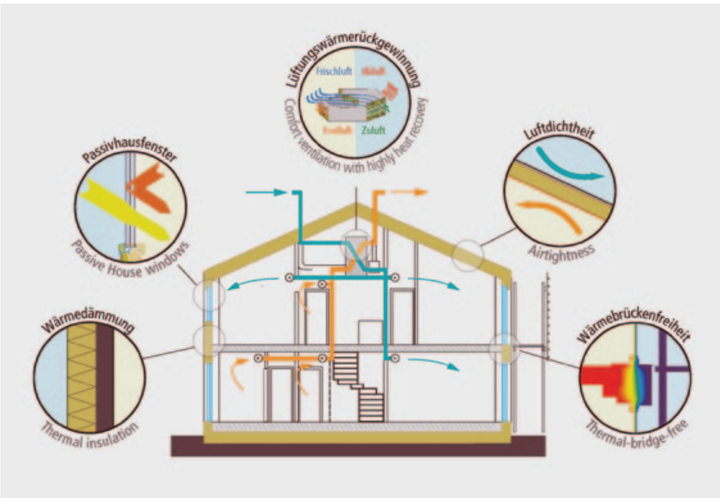


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**3 & 4**
**The Passive House guidelines for cavity wall insulation**
**Passive House Institute**

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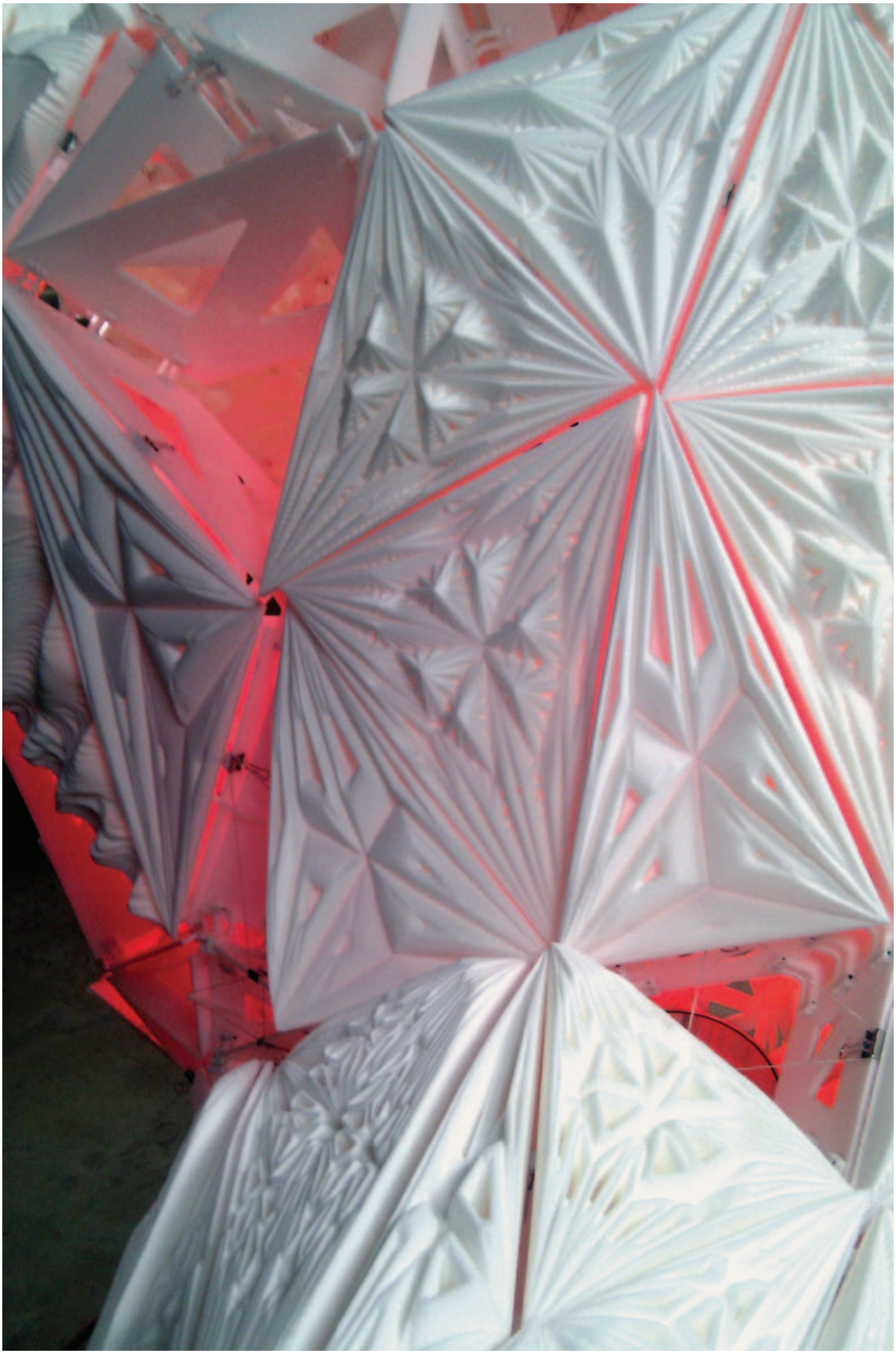
**5**
**Fabricated curvilinear smooth foam surfaces (Molly Wally by marcosandmarjan, 2010)**



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**8**

**9**

**6 *(previous page)* Triangular spikey foam components (Archimera by Marjan Colletti, Guan Lee and Tea Lim, 2012)**

**7 *(previous page)* Cellular rippled milled foam elements (Algae-Cellunoi by marcosandmarjan and Guan Lee, 2013)**

**8 & 9**
**A three-axis CNC machine ready to mill a hard foam board**

# Context

The research is situated in the field of digital design research, in particular morphogenetic design approaches to draughting, modelling, scripting and programming, in conjunction with materials research, CNC and robotic fabrication workflows and technologies.

## Digital contexts

a. Theory

Theories of design through mechanical production have recently been expanded by 'post-digital' theorisation, which questions socially and environmentally unsustainable virtual- and cyber-theory (Benedikt 1992, Wertheim 1999) and environmentally and financially unsustainable architectural production methods. It proposes innovative, commercially feasible applications, techniques and technologies of architectural production with a 'material' approach to architectural digital design.

b. Industrial processes

Innovative file-to-factory processes enable new approaches to the combined tasks of managing materiality (e.g. inherent material properties), logistics (e.g. design, fabrication and assemblage) and engineering (e.g. structural and environmental). In a file-to-factory design protocol, a link between the design-computer and the manufacturing-computer is established. On the one hand, formal decisions influence and re-direct fabrication strategies. On the other, material properties (thickness, elasticity, size), processes (cutting, milling, six-axis robotic movements), and mechanical parameters, affordances and constraints (precision, bed size, arm reach) are constantly fed back into the design process.

c. Design

The focus on foam as a material is directed at the necessity of insulating buildings more efficiently according to EU guidelines. This research suggests that externalising foam insulation would create new opportunities to apply ornamentation, geometry and texture onto large surfaces by harnessing the enormous geometric potential of digital design tools and CNC technologies. [fig. 8 & 9]


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**10**
**Standard wet polyurethane foam from tubes, mixed with additives and stretched to light, filamentous and yet stiff structures (Robotic FOAMing by REX|LAB, University of Innsbruck, 2013)**

## Robotics

a. Industrial contexts

Industrial robots are mechanical handling devices – advanced automation systems – controlled by computers and software. They are useful in a wide variety of tasks, including assembly, material handling, product inspection, welding, laser cutting and painting. Thanks to the advances of digital systems, computational power and programming techniques, more complex tasks can be processed, making robots increasingly flexible, multi-functional, multi-axial, re-programmable, precise and indefatigable. The automotive industry has been the first and largest employer of industrial robots (the first, Unimate, joined General Motors in 1961). The World Robotics Report (2013) gives an estimate of 1.3 million industrial robots in operation today. This number will increase soon, and drastically. Architecture, which has embraced digital and computational technology, is therefore ready to assimilate robotic intelligence into the design and fabrication processes of buildings.

b. Materials

CNC milling of foam is per se a subtractive process, widely used in the nautical, car and aerospace industries, as well as in product design and architecture (milled foam is often used to produce moulds and formworks for casting). However, CNC milled foam has rarely been used as a final product, taking advantage of its insulation, ornamental and translucent qualities.

Robots are generally used to hot-wire cut foam boards to minimise material waste (e.g. the 2010 Periscope Foam Tower by Matter Design). This is also a subtractive process, which eliminates residual material. Robots are also used for additive processes, either as assembly of individual entities (e.g. bricks) or as layering of continuous material (e.g. concrete or clay). Robotic spray-layering additive processes with foam have also been done (e.g. at ETH Zurich).

The process implemented in ProtoRobotic FOAMing is unique. It is neither a subtractive nor an additive process. It is a simulation of natural growth and self-organisation algorithms, achieved by stretching the material. The resulting prototypes resemble biological and natural structures such as bones, tissue and sponges. [fig. 10 – 13]

**11**

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**11**
**Standard wet polyurethane foam from tubes, mixed with additives and stretched to light, filamentous and yet stiff structures (Robotic FOAMing by REX|LAB, University of Innsbruck, 2013)**

**12 & 13**
**The ABB IRB2600 MultiMove system of three six-axis industrial robots, ready to stretch soft foam (REX|LAB, installed at Smartgeometry 2013)**

# Methods

Research methods vary and include:

— Theory: studying historical, cultural and technological literature that supports mechanical fabrication to contextualise and theorise our practice.

— Design: conception, iteration and refinement of complex geometries.

— Analysis: testing bespoke processes and protocols for feasibility and industry requirements.

— Software: developing novel file-to-factory protocols and workflows, in particular the use of software HAL for a MultiMove robotic system.

— Hardware: creating bespoke robotic equipment for the robots.

— Fabrication 'intelligence': innovative and environmentally friendly use of ordinary materials, such as foam.

— Application: opening up further research questions on the retrofit capacity of integrating foam structures into underperforming buildings.

## Digital computational input (modelling, simulating, scripting, scanning) and output by CNC fabrication and 1:1 assembly

The research process was driven by design-led digital fabrication and modelling techniques which advanced through a series of tests and prototypes. The propositional nature of this mode of investigation based on 1:1 scale test-projects and iterations aimed to lead to the generation of larger-scale artefacts.

Initial research focused on applying widely available milling fabrication technologies with clear mechanical limitations (e.g. bed size, z-axis constraints) and geometric limitations (e.g. undercuts, volume constraints) to rigid panels of foam, testing them for fitness and appropriateness. These investigations resulted in four prototypes: Foldsters, Molly Wally, Archimera, The Talented Mr Ripply, and a design proposal for a chapel in Lisbon. [fig. 14 – 18]

Algae-Cellunoi, installed at the 2013 ArchiLAB exhibition Naturalizing Architecture, is an ornamental wall structure for external use. It is composed of numerous cellular foam components resulting from a computational Voronoi pattern that determined the size and complexity of each cell. A sequence of lofted surfaces follows a gradient of punctuated lines and indentations that vary according to the geometric inclination of each surface, similar to growth layouts in sea barnacles and shells. To achieve this, the milling path of each cellular component was digitally controlled and manipulated.

The result has multiple patterns with gaps and crevices. Each cellular component is seeded with terrestrial algae that grow in the ridges between the components. The selected algae strains are *Neochloris texensis*, a soil-based algae of the *Neochloris* genus, and *Trentepohlia.* Furthermore, each cellular component is also designed to host a variety of Objet 3D printed flasks, in which liquid algae can grow for ground fertilisation or for creating a varied natural ecology on the wall. [fig. 19 – 23]

In contrast to standard CNC fabrication, the experimentation with wet foam is neither a subtractive nor an additive process. The process combines fully controlled robotic movements, semi-controlled material mixtures and unpredictable morphogenetic behaviour, which together generate biomimetic formations. These experiments aim to provide a simulation of natural growth and self-organisation algorithms, insofar as the resulting prototypes resemble biological and natural structures such as bones, tissue, sponges and corals.

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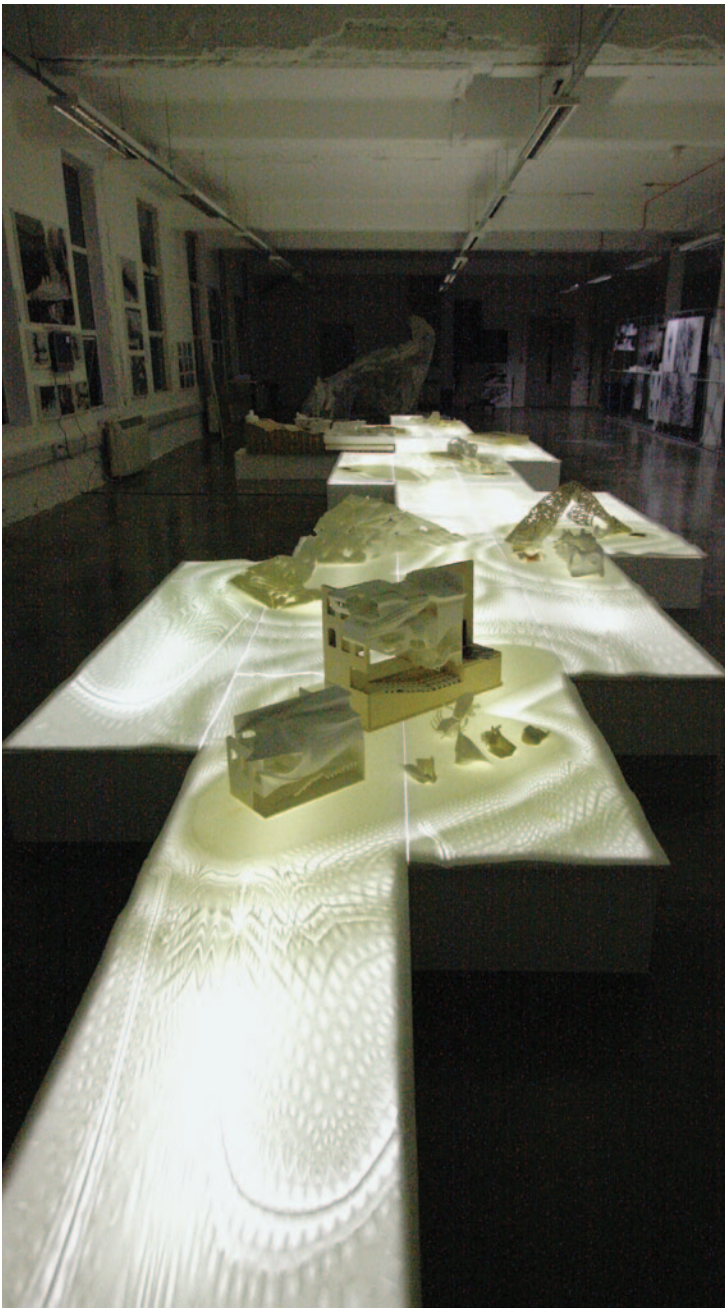
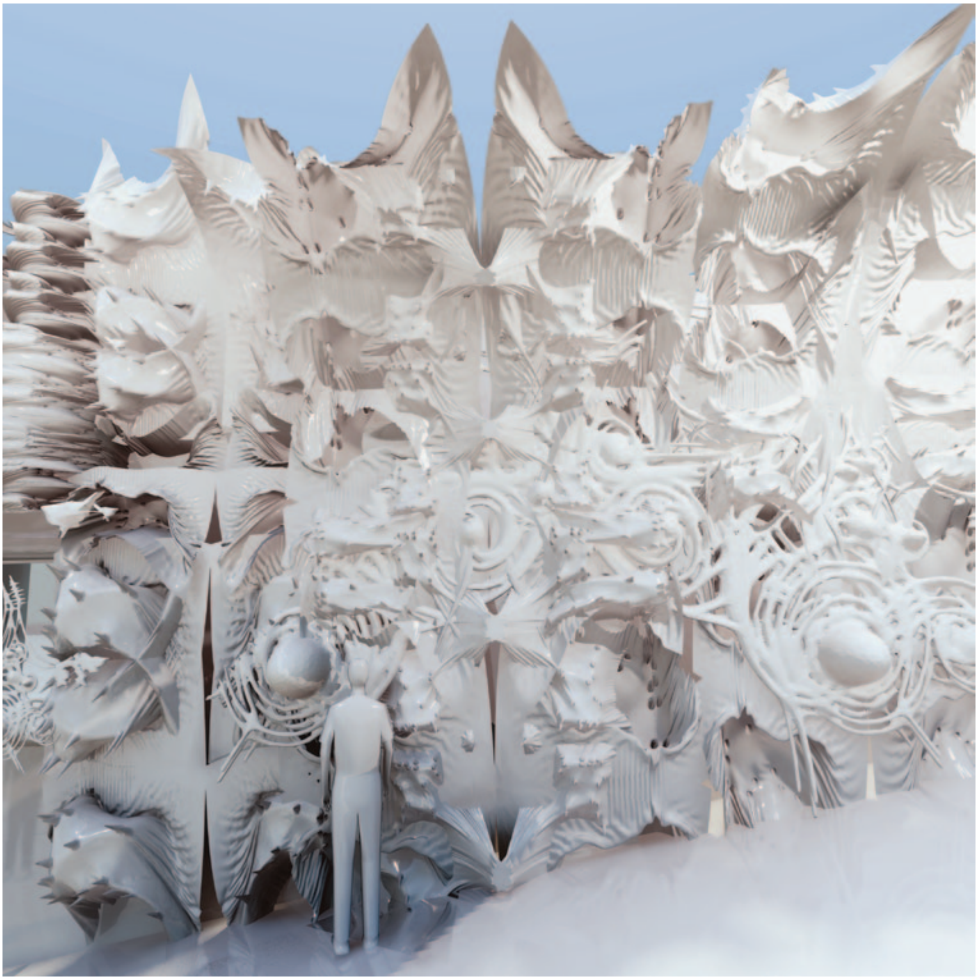


**14**
**Flip-milled foam construction (Molly Wally by marcosandmarjan, 2010)**

**15**
**One-sided joined CNC milled triangulated foam parts (Archimera by Marjan Colletti, Guan Lee and Tea Lim, 2012)**

**16**
**One-sided CNC milled foam (Foldsters by marcosandmarjan, 2010)**

**17**
**One-sided backlit CNC milled foam surfaces (The Talented Mr Ripply by Marjan Colletti, Guan Lee and Tea Lim, 2013)**



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**Flip-milled CNC milled foam assemblage (Lisbon Chapel by marcosandmarjan, 2011)**

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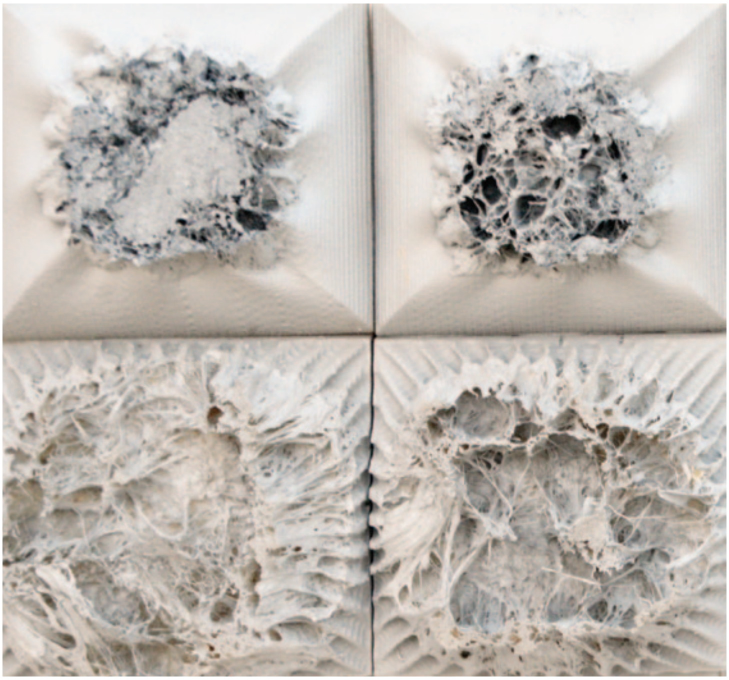

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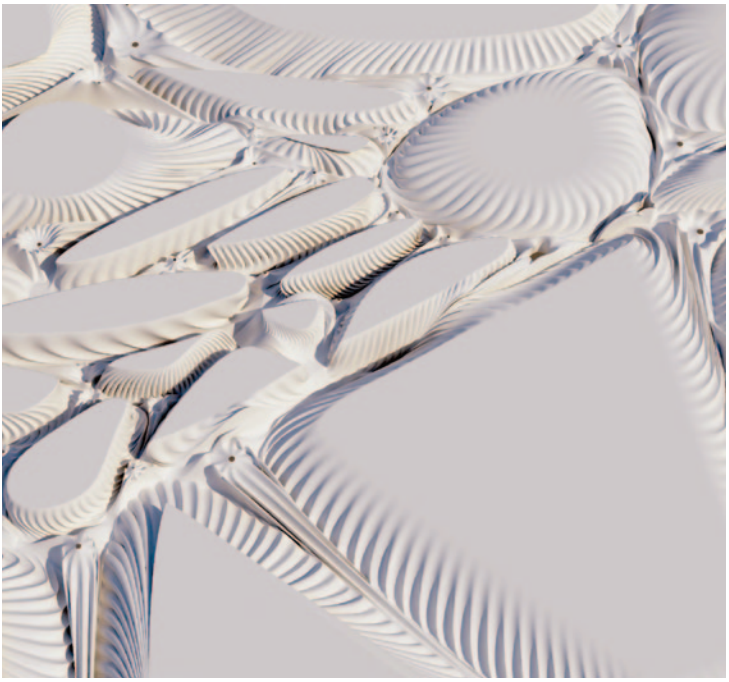

**19**
**Initial algae vessels prototypes (Algae-Cellunoi by marcosandmarjan and Guan Lee, 2013)**

**20**
**Rendering of the back panel of Algae-Cellunoi**

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**View of the milling process for Algae-Cellunoi**

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**Detail of one of the Algae-Cellunoi cells**

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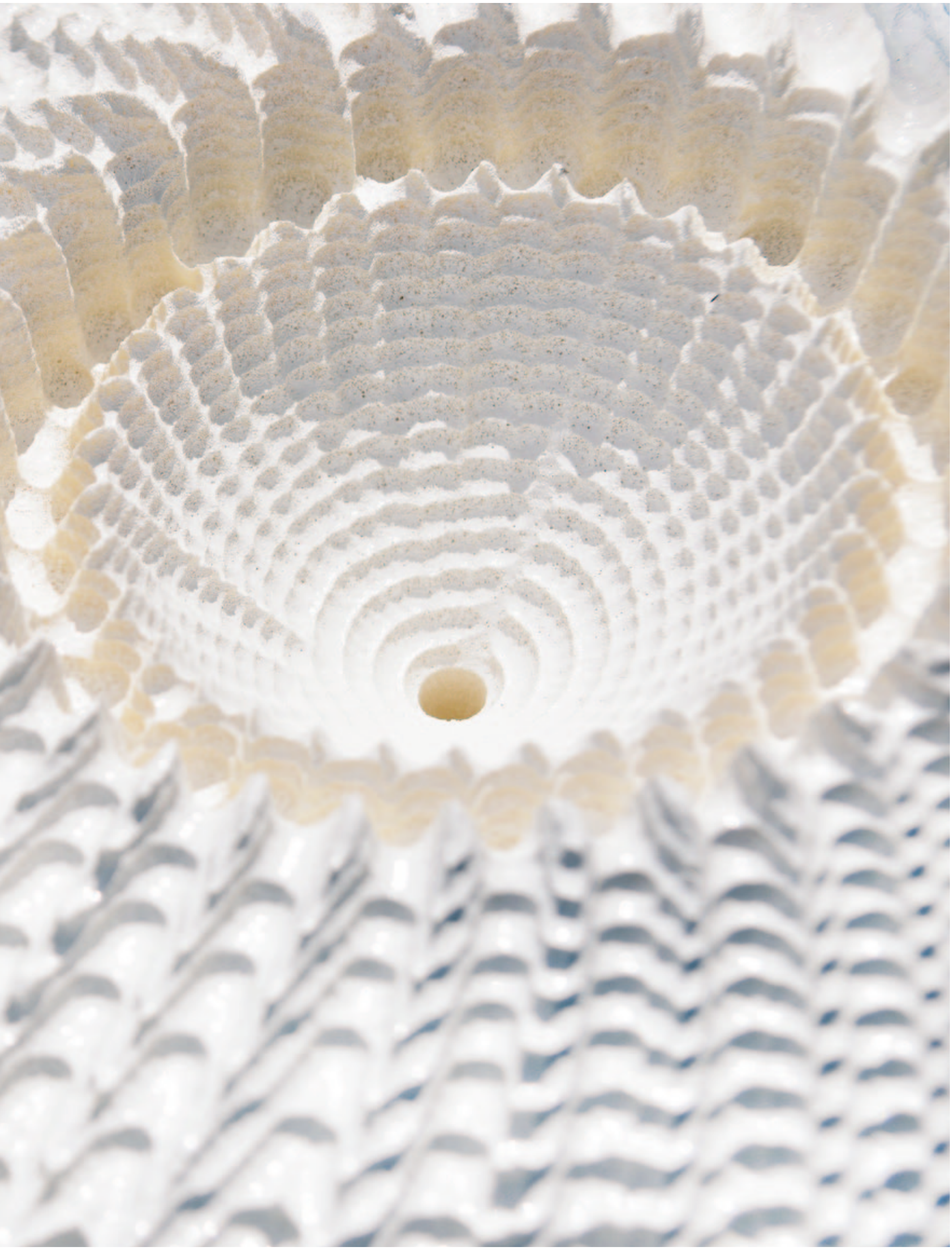

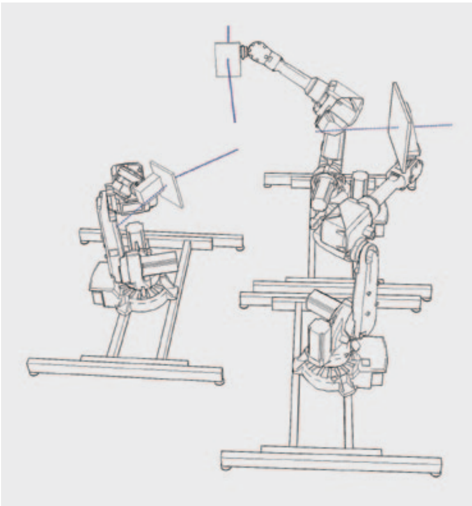

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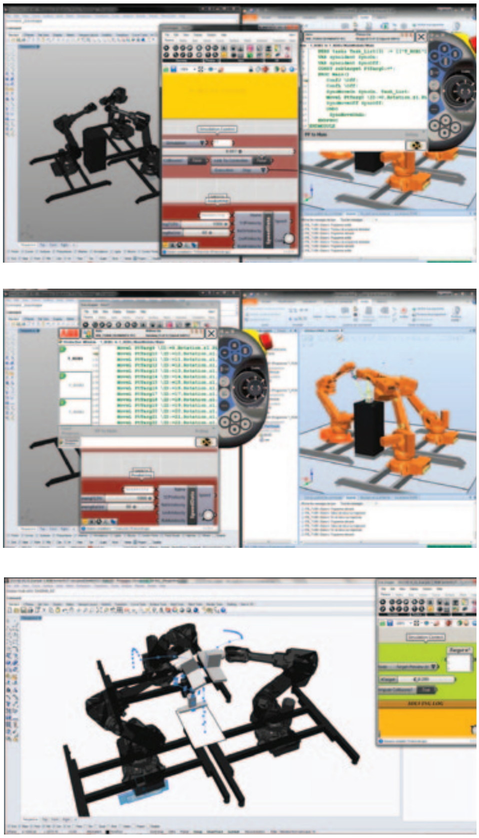

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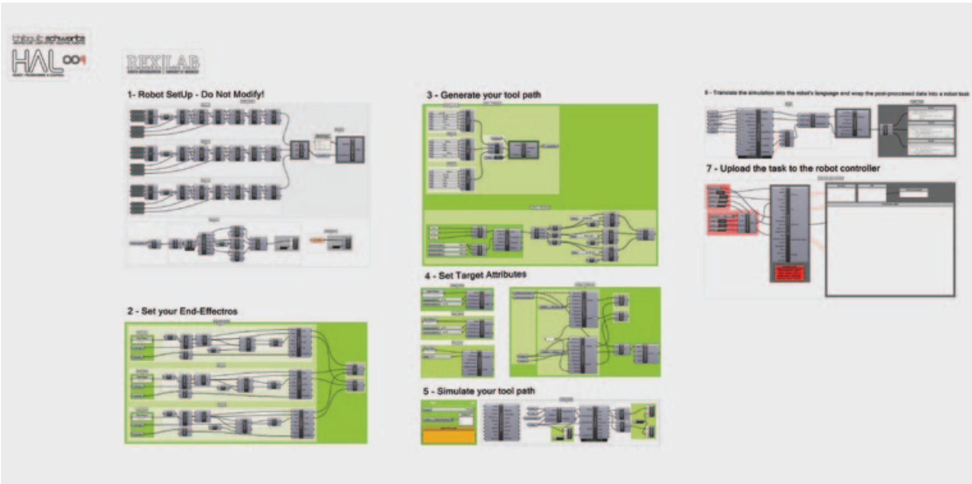


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**23 *(previous page)***
**Detail of one of the Algae-Cellunoi cells**

**24**
**REX | LAB, at the University of Innsbruck's Institute for Experimental Architecture, showing the three ABB IRB2600 Robot MultiMove system**

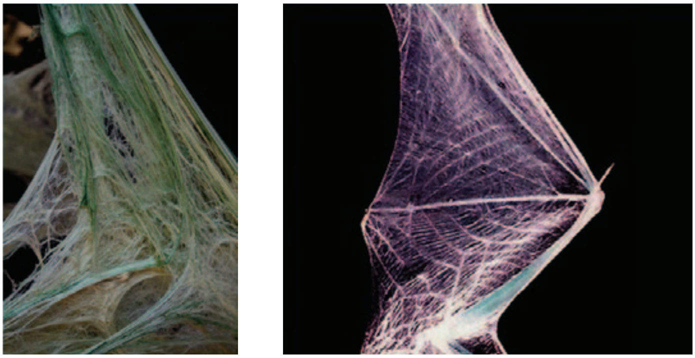
**25 & 26**
**HAL software**

## Digital computational operational control and simulation of machinery (milling machine, 3D printers, robots scripting)

Serial iterations were also used with fast-curing soft foam in tubes (polyurethane) mixed with additives and manipulated by the MultiMove robotic system to become stretched structural elements. More complex CNC machinery was tested using three black multi-axial ABB IRB2600 MultiMove system robots at REX|LAB, the author's laboratory at the University of Innsbruck. [fig. 24 – 26]

Software allows up to four robots together with work positioners, or other devices, to work in cooperation as a fully coordinated fabrication system. Applied to the robot controller system at the lab, the software's performance has been tested in terms of accuracy, speed, cycle-time, programmability and synchronisation with external devices. The system can be controlled by additional software called RobotStudio, developed with ABB. At present, the research has primarily used HAL, an integrated Grasshopper plug-in developed by Thibault Schwartz, which provides a more direct link between 3D modelling and the robots' controls. We believe this is the only MultiMove system with this particular software configuration.

The project makes use of the robots and establishes stretching as methodology to achieve self-organising structural prototypes. Experimenting with soft foam in tubes has revealed how it can dramatically grow in size and become structural through a systematic process of stretching. Mixed with additives, the unstructured malleable mass can be stretched into stiff yet light, filamentous and porous structures. [fig. 27 – 30]



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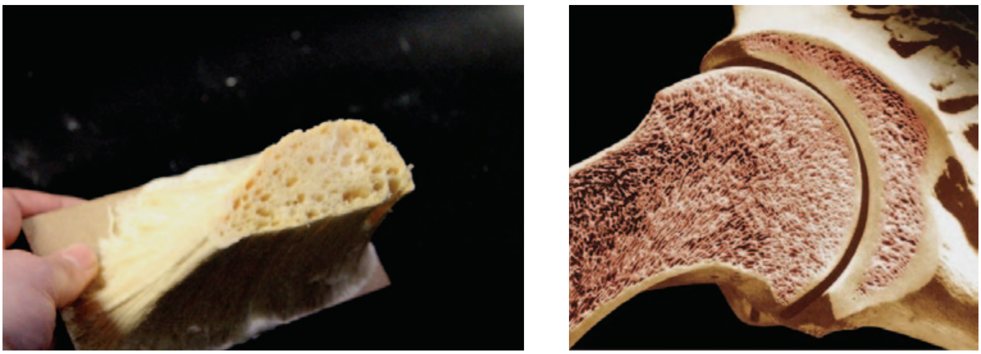

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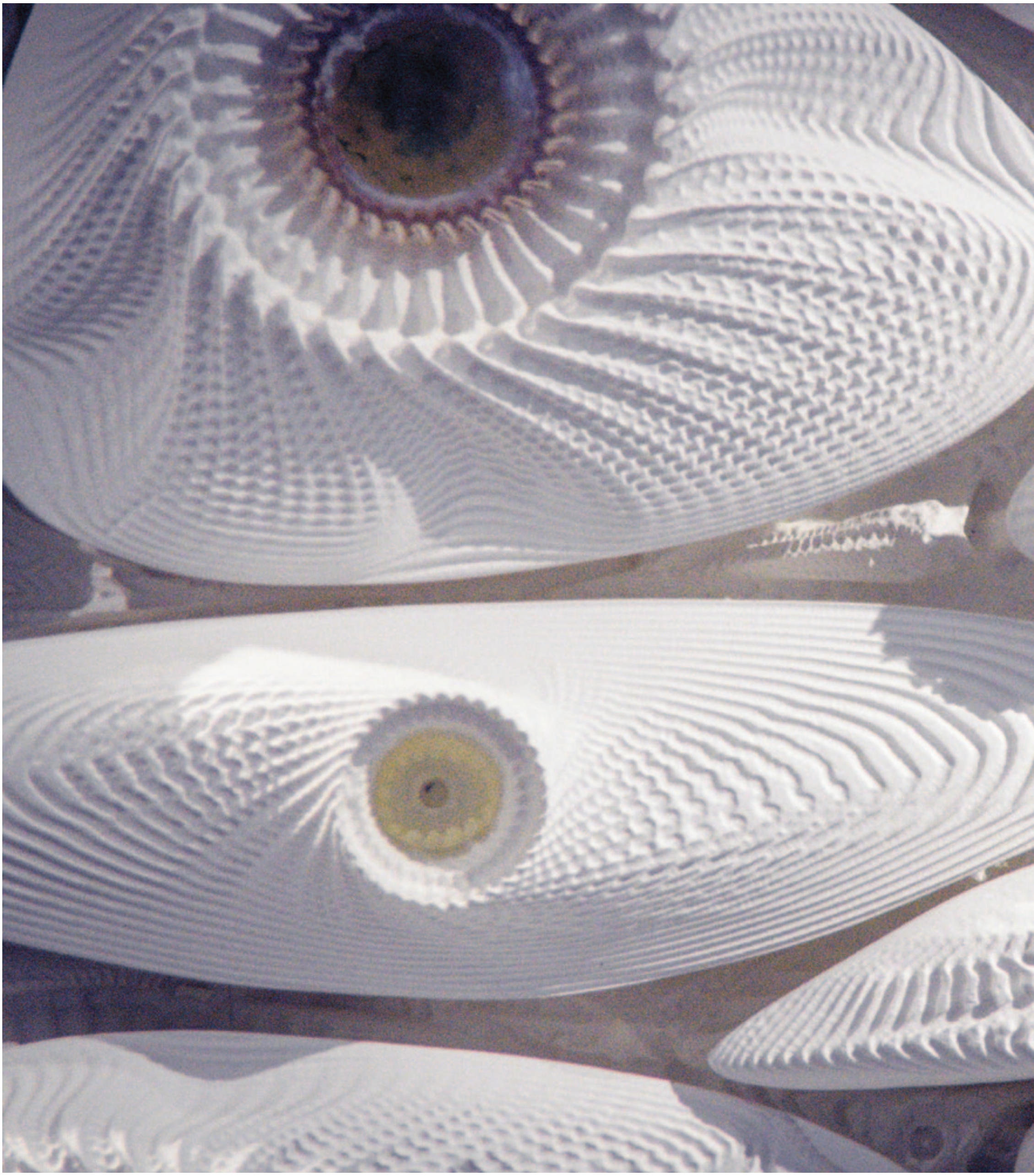
**27–29**
**Examples of self-generative biomimetic structures resulting from stretching foam (comparative studies by Dirk Krolikowski, Smartgeometry 2013)**


REXLAB
REXLAB

**30**
**The ABB IRB2600 MultiMove system of three six-axis industrial robots, stretching soft foam (REX|LAB, installed at Smartgeometry 2013)**



**31**
**Algae-Cellunoi**
**(by marcosandmarjan and Guan Lee, ArchiLAB 2013)**

# Dissemination

Earlier research iterations and prototypes manipulating rigid foam panels have been exhibited at the Haus der Architektur, Graz (2012), Zezeze Architecture Gallery, Tel Aviv (2011), Royal Festival Hall, London (2010) and Christ Church Spitalfields, London (2010).

Algae-Cellunoi implements much of this earlier research into a single wall piece. It was exhibited at Naturalizing Architecture, the ArchiLAB 2013 exhibition at the FRAC Centre (Fonds Régional d'Art Contemporain de la région Centre) in Orléans (Sep 2013 – Feb 2014). Other key exhibitors included: Gramazio & Kohler, Michael Hansmeyer, Iris van Herpen, Junya Ishigami, Achim Menges, Neri Oxman, and Casey Reas. [fig. 31 & 32]

Robotic FOAMing has been selected as one of the workshop cluster topics by: Smartgeometry at UCL (London, Apr 2013); Architecture Challenge 13, organised by the Tallin Architecture Biennale and University of Applied Arts, Vienna (Tallin, Aug 2013); Rob|Arch 2014: Robotic Fabrication in Art, Architecture and Design at University of Michigan (Ann Arbor, May 2014); and Fabricate at ETH Zurich (Feb 2014). It has also been exhibited at the Prague Experimental Architecture Biennial (2013); AUT: Architektur und Tirol in Innsbruck (2013); and the Tallinn Architecture Biennale (2013).

### Keynotes

TADA Taiwan Centre for Art, Design and Architecture, Taiwan (Apr 2008)

Girasole workshop, Bolzano (Jan 2013)

Experimental Architecture Biennial symposium, Prague (May 2013)

Architecture and Sciences: A New Naturalness, ArchiLAB 2013 symposium, Orléans (Oct 2013)

Baroque to Neo-Baroque: Emotion and the seduction of the Senses, University of Melbourne and the National Gallery of Victoria (Nov 2013)

## Lectures

South Bank University, London (Jan 2008)
University of Oslo (Mar 2008)
Tunghai University, Taiwan (Apr 2008)
Building Centre, London (May 2008, Sep 2009)
University of Lund (Sep 2008)
Royal Danish Academy of Fine Arts, Copenhagen (Mar 2009)
École Polytechnique Fédérale de Lausanne (May 2009)
Icon Minds conference, London (Oct 2009)
University of Cambridge (Jan 2010)
Chelsea College of Art and Design, London (Feb 2010)
Southern California Institute of Architecture, Los Angeles (Mar 2010)
LA Forum, Los Angeles (Mar 2010)
University of Innsbruck (Mar 2010)
Christ Church, London (Apr 2010)
Tate Liverpool (May 2010)
University of Liverpool (May 2010)
Architectural Association, London (May 2010)
Palazzo Ca' Salvioni, Venice (Aug 2010)
University of Texas at Arlington (Sep 2010)
Neo-Baroque Research Group, Las Vegas (Oct 2010)
Universidad Francisco Marroquín, Guatemala City (Oct 2010)
Technische Universität, Vienna (Jan 2011, Oct 2011)
Strelka Institute for Media, Architecture and Design, Moscow (Feb 2011)
Tel Aviv University (Mar 2011)
Zezeze Architecture Gallery, Tel Aviv (Mar 2011)
Austrian Cultural Forum, London (Mar 2011)
University of Luxembourg (Feb 2012)
Kunsthaus Graz (May 2012)
University of Innsbruck (Jun 2012)
Staatliche Akademie der Bildenden Künste, Stuttgart (Oct 2012)
FutureLab, Munich (Nov 2012)
Carleton University, Ottawa (Feb 2013)
Smartgeometry, UCL, London (Apr 2013)
Urban Prototyping Festival, Imperial College London (Apr 2013)

# Bibliography

Michael Benedikt (ed.), Cyberspace: *First Steps.* Cambridge, MA and London: MIT Press, 1992.

Marjan Colletti, *Digital Poetics: An Open Theory of Design-Research in Architecture.* Farnham and Burlington, VT: Ashgate Publishing, 2013.

Greg Lynn, *Animate Form.* New York: Princeton Architectural Press, 1999.

Margaret Wertheim, *The Pearly Gates of Cyberspace: A History of Space from Dante to the Internet.* London: Virago Press, 1999.

World Robotics Report, 'Executive summary' (2013): www.worldrobotics.org/uploads/media/Executive_Summary_WR_2013.pdf

**32**
**Algae-Cellunoi**
**(by marcosandmarjan**
**and Guan Lee,**
**ArchiLAB 2013)**

## Related publications by the researcher(s)

**pp. 34–46**
**Marjan Colletti and Marcos Cruz, 'Convoluted flesh: a synthetic approach to analog and digital architecture', in *Studioplex Vol. 1: Architecture, a timely matter*, UCLA Architecture and Urban Design (2012), 106–117.**

**pp. 47–51**
**Marjan Colletti, 'The (fr)agile beauty of architecture: ProtoRobotic FOAMing as an expression of Neo-Materialism', *Archithese* 3.2013 *Weak Materiality* (Mar 2013): 54–57.**

**pp. 52–55**
**'marcosandmarjan: Robotic FOAMing 2013', in *Naturaliser Architecture/Naturalizing Architecture: ArchiLab 2013*, ed. Marie-Ange Brayer and Frédéric Migayrou. Orléans: FRAC Centre (2013), 264–267.**

**pp. 56–60**
**'An example of [en]coding Neo Materialism: ProtoRobotic FOAMing', in *En]Coding Architecture: Code, Architecture, Robotic Fabrication, Material, Intelligence and a New Computational Theory*, ed. Liss Werner (Carnegie Mellon University, forthcoming 2014).**

## Related writings by others

**pp. 62–64**
**‘Robotic FOAMing’, *Smartgeometry* 2013 (Apr 2013): http://smartgeometry.org/index.php?option=com_community&view=groups&task=viewgroup&groupid=38**

**pp. 65–70**
**Wanda Lau, ‘Window into the future of design: Scenes from Smartgeometry 2013’s exhibition’, *Architect: The Magazine of the American Institute of Architects* (22 Apr 2013): www.architectmagazine.com/design/window-into-the-future-of-design-scenes-from-smartgeometry-2013s-exhibition.aspx**

**pp. 71–76**
**Marios Tsiliakos, ‘Robotic Foaming – Marjan Colletti & Rex-Lab’, *Archisearch.gr* (13 May 2013): www.archisearch.gr/article/1104/robotic-foaming--marjan-collett**

**pp. 77–78**
**Kadri Tamre, ‘Uued arhitektuuri-ideed sünnivad robotite abil’, *SIRP* 20.3442 [Estonia] (17 May 2013): 16. www.sirp.ee/index.php?option=com_content&view=article&id=18213:uued-arhitektuuri-ideed-suennivad-robotite-abil&catid=20:arhitektuur&Itemid=25&issue=3442**

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**Nathan King, Georg Grasser, Kadri Tamre and Allison Weiler, ‘Robotic control of material behavior and fabrication of phase-change materials’ [REX|LAB workshop, accepted for Rob|Arch 2014: Robotic Fabrication in Art, Architecture and Design, May 2014].**

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