FABRICATE: MAKING DIGITAL ARCHITECTURE BRINGS TOGETHER THE WORK OF DESIGNERS, ENGINEERS AND MAKERS WITHIN ARCHITECTURE, CONSTRUCTION, ENGINEERING, COMPUTATION, AND MANUFACTURING. COVERING A CROSS SECTION OF SCALES AND TYPOLOGIES, THE PUBLICATION FEATURES 38 ILLUSTRATED CASE STUDIES OF COMPLETED BUILDINGS, NEW WORKS IN PROGRESS, AND THE LATEST RESEARCH IN DESIGN AND DIGITAL MANUFACTURING. PRACTICES INCLUDED FOSTER + PARTNERS, ZAHA HADID ARCHITECTS, ARUP, BURO HAPPOLD, AMANDA LEVETTE ARCHITECTS, RON ARAD ASSOCIATES, AND RENOWNED INSTITUTIONS DELFT, HARVARD, MIT, THE BARTLETT, CITA, AND THE AA. PUNCTUATING CHAPTERS ON ACADEMIC AND PRACTICE BASED RESEARCH, CONVERSATIONS BETWEEN WORLD LEADING EXPERTS MARK BURRY, PHILIP BEESLEY, MATTHIAS KOHLER, NERI OXMAN, MARK WEST, MICHAEL STACEY, HANIF KARA AND SEAN HANNA DISCUSS THEMES ON DRAWING TO PRODUCTION, BEHAVIOURAL COMPOSITES, ROBOTIC ASSEMBLY, AND DIGITAL CRAFT. AS THE SCOPE AND DIVERSITY OF WORK SHOWN HERE VERY CLEARLY CONVEYS, NEW PROTOCOLS OF ENGAGEMENT BETWEEN THE DESIGN AND MAKING OF DIGITAL ARCHITECTURE OFFER DISCIPLINES ON ALL SIDES THE CHALLENGE TO RECONSIDER FABRICATION AS A DESIGN ACTIVITY, AND TO RETHINK HOW THE NECESSARY EXPERTISE TO MASTER THIS FIELD CAN BE ACQUIRED.

ISBN 978–1–926724–18–8

Autodesk UCL Riverside Architectural Press

FABRICATE: MAKING DIGITAL ARCHITECTURE RUAIRI GLYNN & BOB SHEIL

FABRICATE

RUAIRI GLYNN & BOB SHEIL

FABRICATE: MAKING DIGITAL ARCHITECTURE RUAIRI GLYNN & BOB SHEIL

Autodesk®

UCL

We wish to make a special thanks to Marilena Skavara, who has tirelessly assisted us in organising FABRICATE 2011's conference, publication and exhibition.

Ruairi Glynn and Bob Sheil

18–19 **CONTENTS**

20–21 **INTRODUCTION**
RUAIRI GLYNN

22–27 **RESEARCH PAVILION, ICD/ITKE**
ACHIM MENGES, SIMON SCHLEICHER & MORITZ FLEISCHMANN

28–31 **THAW**
METTE RAMSGARD THOMSEN, KARIN BECH & MARTIN TAMKE

32–39 **FABRICATING INDETERMINATE PRECISION**
NAT CHARD

40–47 **FAB(BOTS)**
MARTA MALÉ-ALEMANY, JEROEN VAN AMEIJDE & VICTOR VIÑA

48–51 **LOGIC MATTER**
SKYLAR TIBBITS

52–55 **CNCATENARY**
ERMIS ADAMANTIDIS

56–61 **UNIKABETON PROTOTYPE**
ASBJØRN SØNDERGAARD & PER DOMBERNOWSKY

62–69 **SCANLAB**
WILLIAM TROSSELL & MATTHEW SHAW

70–73 **FREE FORM METAL INFLATION & THE PERSISTENT MODEL**
PHIL AYRES

74–85 **MATTER & MAKING**
FABLAB, TAUBMAN COLLEGE OF ARCHITECTURE

86–89 **MATERIAL ANIMATION**
NICK PUCKETT

90–93 **MINIMAL COMPLEXITY**
VLAD TENU

94–97 **TERRA THERMA**
PETER WEBB & MICK PINNER

98–105 **INVESTIGATIONS IN DESIGN & FABRICATION AT HYPERBODY**
MARCO VERDE, MARKDAVID HOSALE & JELLE FERINGA

106–109 **PROTOTYPE FOR A SPATIALISED INSTRUMENT**
MISHA SMITH

10–11 **FOREWORD**
ROBERT AISH

12–13 **FOREWORD**
ALAN PENN

14–15 **ACKNOWLEDGEMENTS**
RUAIRI GLYNN & BOB SHEIL

INTRODUCTION

ACADEMIC

154–155 **CONTENTS**

156–157 **INTRODUCTION**
BOB SHEIL

158–163 **VILLA NURBS**
ENRIC RUIZ-GELI & HIS TEAM AT CLOUD 9,
FREDERIC AMAT & TONI CUMELLA

164–167 **C-STONE & C-BENCH**
PETER DONDERS

168–175 **GALAXY SOHO**
CRISTIANO CECCATO

176–183 **MEDIA-ICT**
ENRIC RUIZ-GELI
& HIS TEAM AT CLOUD 9

184–191 **MEADS REACH BRIDGE**
TIM LUCAS

192–195 **THE SPHERE**
OLIVER TESSMANN, MARK FAHLBUSCH,
KLAUS BOLLINGER, MANFRED GROHMANN
& MARKUS SCHEIN

196–201 **THE AGENCY OF CONSTRAINTS**
JOE MACDONALD

202–207 **THE RICHMOND SPEED SKATING OVAL ROOF**
GERALD EPP, LUCAS EPP & SANTIAGO DIAZ

208–215 **THREE PROJECTS: A COMPARATIVE STUDY**
AL_A

216–221 **MULTI-SPHERICAL MIRRORED SCULPTURE**
CHIARA TUFFANELLI

222–227 **MÉDIACITÉ**
PAUL MADDEN & GEOFF CROWTHER

228–231 **WAVED WOODEN WALL**
HANNO STEHLING & FABIAN SCHEURER

232–235 **RADIOLARIA PAVILION**
ANDREA MORGANTE

236–239 **LOUVRE ABU DHABI**
BENJAMIN S KOREN

240–243 **LARGE, COMPLEX, PERFORATED ENCLOSURES IN EXTREME ENVIRONMENTS**
AL FISHER & SALMAAN CRAIG

244–249 **DESIGN POTENTIAL FOR LARGE-SCALE ADDITIVE FABRICATION**
XAVIER DE KESTELIER

252–257 **ENDNOTES**

258–259 **AUTHORS BIOGRAPHIES**

260 **COLOPHON**

112–115 **BIOGRAPHIES**

116–123 **MATTHIAS KOHLER**
HANIF KARA

124–133 **MARK BURRY**
MARK WEST

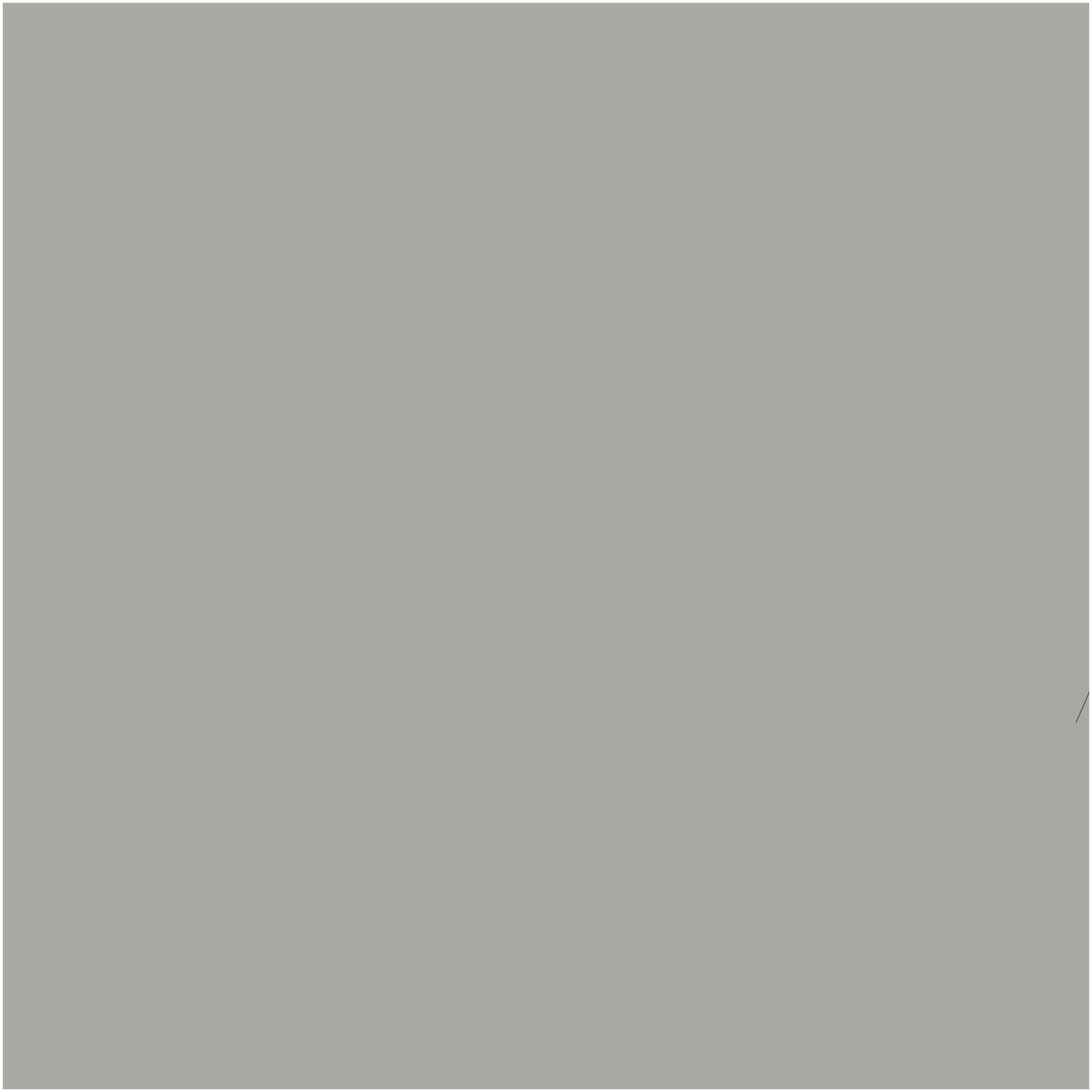
134–143 **PHILIP BEESLEY**
MICHAEL STACEY

144–151 **NERI OXMAN**
SEAN HANNA

Q&A

PRACTICE

END



INTRODUCTION

FABRICATE: Making Digital Architecture gathers together a unique selection of research and exploratory prototypes and records the creative thinking of innovative designers and researchers. Fabrication depends on the ability of the designer to harness the properties of materials and to anticipate how these can be transformed by the sequencing of manufacturing operations. It is not just the fabrication processes described here that are important but also how these relate to, or express, design intent.

Behind many of these examples lies the creative use of design computation tools. Again, it is not just the computation tools that are important but how these relate to or express design intent and can be used as an intermediary between the designer and the fabrication process. Are these computation tools primarily focused on creating computational analogues of tangible aspects of design, or on abstractions? Such abstractions might be conditional, dependency, repetition, iteration, recursion, convergence, encapsulation and inheritance. How do these abstractions intersect with concepts used in contemporary design thinking such as commonality, variation, differentiation, adaptation and emergence?

Essentially we have a network of connections between design (intent), computation (abstraction), fabrication (realisation), the resulting building (as artefact) and the building user (and their 'user experience'). Here we see 'fabrication' as an important component within a larger system. Both fabrication processes and design computation can be viewed as important design tools. What is the relationship between tools and design? Tools provide possibilities, from these possibilities we discover advantages, advantages become a convenience, and convenience can too easily become a convention. There are alternatives: rather than supporting just the more efficient execution of conventional tasks, tools can encourage new ways of thinking. The creative use of a tool should include opportunities for the designer to embed his own design logic within that tool. Such customisation should be recognised as a key aspect of design creativity. A creative tool is one that facilitates this customisation and can be used beyond what was envisaged by the original tool builder. Tools, therefore, embody conceptual knowledge. Harnessing tools may relieve the designer of some physical and mental effort but also require the acquisition of this conceptual knowledge. Never be limited by the available tools. Think beyond the tool. Tools should challenge the designer. The designer should challenge the tools. Become you own tool builder. Challenge yourself.

When you read the different sections of this book, I would like to encourage you to ask a number of critical questions. Is the design intent explicitly stated? Or, by reading the text and reviewing the images, is it possible to recover some sense of what this design intent might be? What was the relationship between the fabrication process and this design intent? Was the intent to explore a particular material or fabrication process (which, at a research or 'proto-architecture' level of inquiry, is quite legitimate) or was fabrication being used to realise some broader design intent? What computing was used? Was this computing primarily focused on a digital representation of the 'tangible' (geometric form, material properties and manufacturing operations)? Or were additional computational abstractions used and how did these contribute to the design process or design outcome? What additional concepts, insights or possibilities did the designer acquire through the use of these abstractions? And (to rephrase the previous questions) what was the relationship between the computational abstraction and design intent? Was the intent to explore the abstraction (which, at a research 'proto-architecture' level of inquiry, is quite legitimate), or was the abstraction being used to realise some broader design intent?

FOREWORD ROBERT AISH

DIRECTOR OF SOFTWARE DEVELOPMENT,
AUTODESK PLATFORM SOLUTIONS

The progress of architectural practice can be characterised by two opposing forces: a convergent force driven by the spirit of the times and a drive for innovation. Common themes and interests emerge from the cultural milieu, which seem to act as 'attractors' for the field of practice and contemporary fashion. One could imagine this in terms of a flocking algorithm, in which individual birds move towards the heart of the flock; this dynamic giving rise to the identity of the flock – the similarities between the paths of the individuals which lead it to cluster and cohere as a discernable object – and the trajectory of the whole flock over time.

Opposing this is a drive for innovation. Innovators aim to distinguish their practice from that of others and current fashions. They continually strive to fly away from the flock, and where it has been in the past, to explore new territory. However, by trying to get away from the flock the innovators merely help determine its direction of flight. They become the moving front edge of the flock. From time to time different groups of innovators choose to explore different trajectories and the flock may divide, often only to come together again some time later.

The spirit of the times is often summed up by an 'aesthetic' – the formal and material properties of buildings that are most easily seen and emulated. However, underlying these surface details are at least three sets of concerns by which practices seek to identify themselves and to distinguish themselves from others: an ethical position (an attitude towards sustainability, for example); a spatial practice (often an approach to the spatialisation of the social) and a working process (the methods through which the practice pursues its design).

Of course, from an individual's point of view inside a flock it can be hard to see its shape, even to see that you are part of a flock at all. The role of the critic, the curator and the conference organiser is to give shape to the flock – to help create the cultural milieu by defining and reflecting back on the individual the dynamic of the group as a whole; to help make sense of the apparently random and divergent paths of individuals seen close up. This is the role of this conference and book.

Here our focus is primarily on 'working process' – the processes in design and fabrication by which material components are shaped and brought together to produce spatial and formal objects. The effects of computing on architecture are far reaching. They bring the ability to control fabrication digitally, to drive cutting, bending and assembly; to simulate and optimise material performance, to control geometry with precision. They bring the potential to put the designer once again in direct control of the craft of material shaping and construction, something unseen since the medieval craftsman masterbuilder gave way to the divisions of labour – and the constraints of symbolic representation of the production drawing – that characterise the modern industry. The fast-moving front edge of the flock is an exciting place to be.

FOREWORD ALAN PENN PROFESSOR OF ARCHITECTURAL & URBAN COMPUTING, DEAN OF THE BARTLETT FACULTY OF THE BUILT ENVIRONMENT, UCL

ACKNOWLEDGEMENTS RUAIRI GLYNN & BOB SHEIL

FABRICATE: Making Digital Architecture is a selection of articles by designers, engineers and makers within architecture, construction, engineering, manufacturing and computation. It is published alongside FABRICATE 2011, an internationally peer-reviewed conference held at The Bartlett School of Architecture, University College London, from 15–16 April 2011, for which over 240 submissions were received from 31 countries, including 35 higher education institutions and 28 international consultancy firms. We are immensely grateful to all who submitted and also to our panel of 18 advisors and reviewers for their council, patience and time.

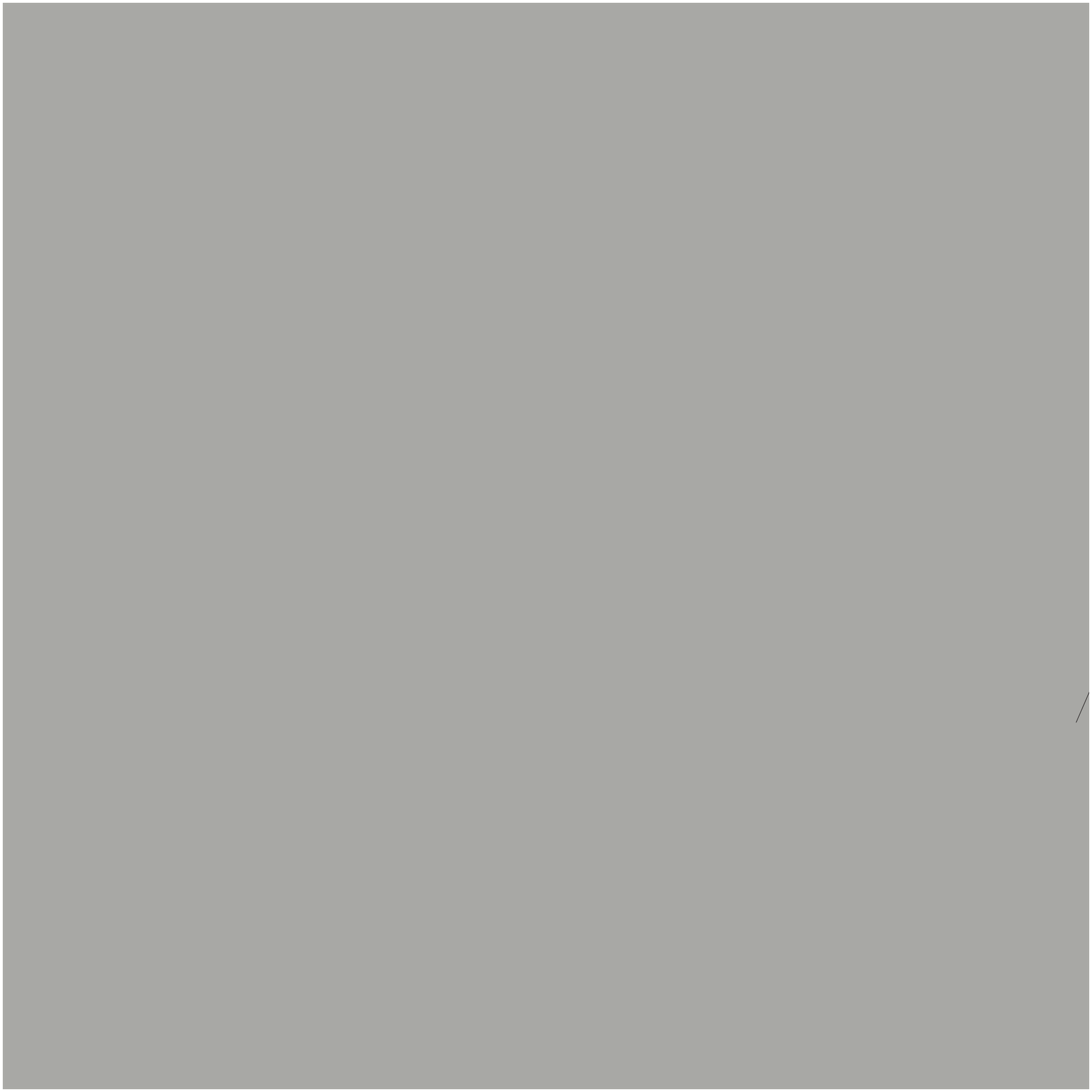
The works presented here are from leading consultancies such as Foster + Partners, Zaha Hadid Architects, Arup, Buro Happold, Amanda Levete Architects and Ron Arad Associates, and from renowned institutions such as Delft, Harvard, MIT, The Bartlett, CITA and the AA. Projects cover a broad cross-section of scales and typologies of contemporary architectural and engineering innovation, including recently completed buildings, new works in progress and the latest research in design and digital manufacturing. Together these works encompass much of the breath, complexity and new skills required in making architecture with digital tools and techniques. Punctuating the chapters on Academic- and Practice-based research, our invited keynotes to FABRICATE 2011 – Mark Burry, Philip Beesley, Gramzio & Kohler and Neri Oxman share their thoughts with esteemed experts, Mark West, Michael Stacey, Hanif Kara and Sean Hanna.

FABRICATE 2011 was planned to follow the 'Digital Architecture London' Conference and 'Digital Hinterlands' exhibition organised by The Bartlett UCL in September 2009, and the associated publication *Digital Architecture: Passages Through Hinterlands*, edited by Ruairi Glynn and Sara Shafiei. FABRICATE is also in some way a response to the highly successful 'Fabrication' Conference held in Waterloo in 2004, organised by the Association for Computer Aided Design in Architecture (ACADIA). We thank its Chair, Philip Beesley who has been a constant support.

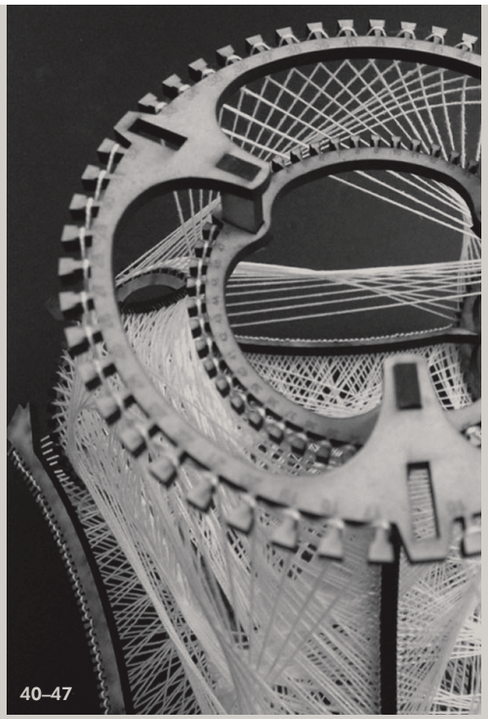
Now, some six years later, the novel technologies and techniques discussed then are becoming commonplace in academic institutions and a growing breed of young architect-fabricators are challenging conventional modes of practice, relocating design to a position where material knowledge is both tacitly understood and fully exploited. We believe that the work presented here demonstrates many of the opportunities fabrication technologies offer the designer for greater control, ownership and influence over the processes by which our built environment is generated and regenerated.

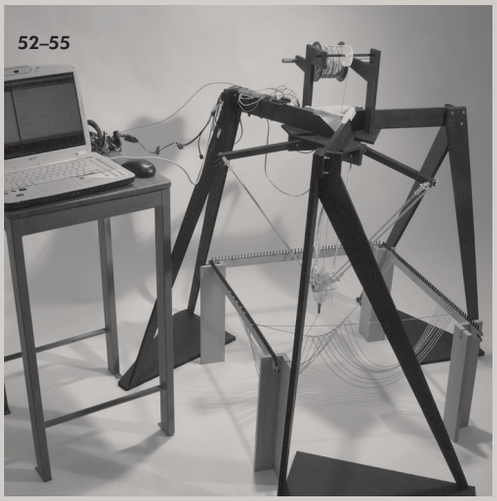
It was by pure chance that both this publication and the associated event represent work from practice and academia in equal measure. Too much could be read into such an outcome but, at the very least, it reveals that our invitation to explore FABRICATE as a theme has attracted significant and broad interest across the key threshold, where innovation, vision, feasibility and collaboration meet. As the scope and diversity of work shown here very clearly conveys, new protocols of engagement between the design and making of digital architecture offer disciplines on all sides the challenge to rethink fabrication as a design activity, and to rethink how the necessary expertise to master this field can be acquired.

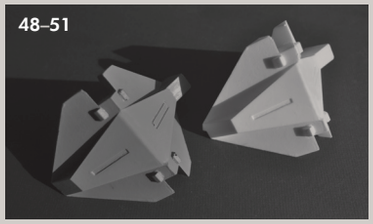
We owe thanks to a large number of friends and colleagues. Firstly, to The Bartlett Architecture Research Fund for its vital support at the very early stages of planning, to our partners, The Building Centre, for their support and advice, to Dezeen for their promotional efforts, and to Autodesk for their generous support towards the book. Amongst a large group of generous and supportive colleagues, we particularly wish to thank Professors Alan Penn, Jane Rendell and Stephen Gage, for their valued council and guidance, and Dr Marcos Cruz for his support and cooperation. For our striking conference identity, meticulous publication design and her patience, our thanks to Emily Chicken. We are indebted to our esteemed group of peer reviewers and panel chairs onto whom we transferred a workload more than twice the agreed quantity, and whose extensive, professional and thorough response, the quality of this endeavour rests upon. And last but certainly not least, to our present and former students whose appetite, verve and enthusiasm for ambitious experimentation continues to urge us on.

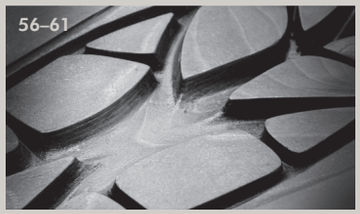


ACADEMIC

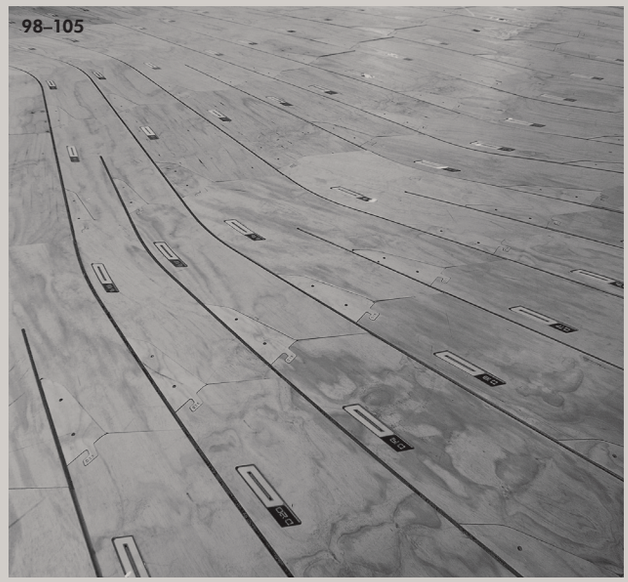

40–47


52–55

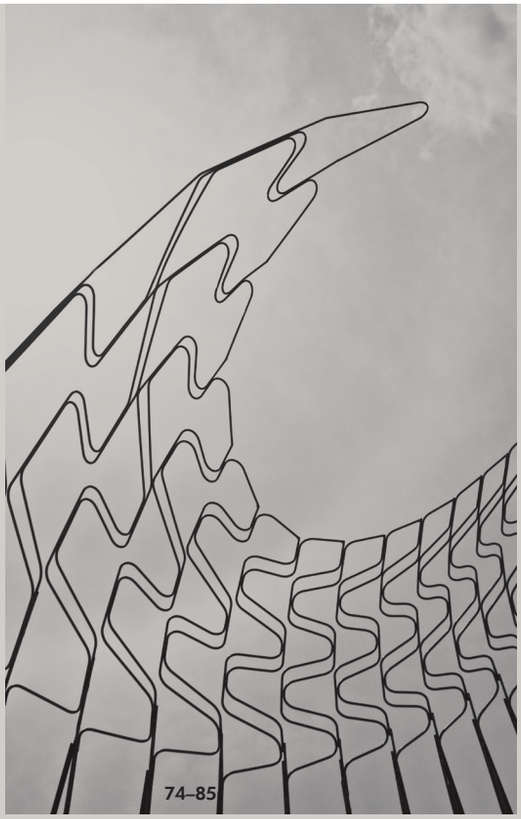

48–51

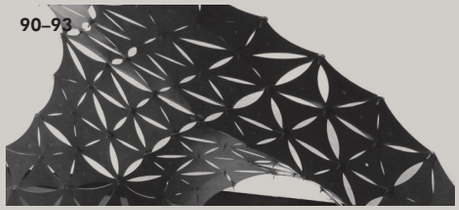

56–61

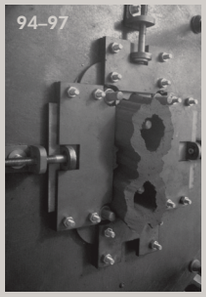

28–31


98–105


62–69







ACADEMIC CONTENTS

In dividing architectural research between practice-based and academic classifications we raise a dichotomy typical of but problematic to the discipline. Distinctions made between architect, programmer and structural, mechanical and material engineer are equally problematic. Produced by teams of multidisciplinary practitioners this publication scrutinises the demarcation of roles in the construction industry, particularly that of the architect, suggesting alternative models of design through to production. In this section we witness how schools of architecture are leading and responding to changes in our discipline brought about by the accelerating adoption of digital fabrication technologies. Case studies come from multi-institutional programmes, departmental research groups, doctoral candidates, design units and individual graduates. Much of it is proto-architectural in its realisation, exploring the performative capabilities and spatial qualities of material systems. The methods and experiences shared clearly demonstrate that the process of design to production is not as linear and reductive as some 'file-to-factory' evangelists might suggest. Feedback systems rich in iterative physical testing, coupled with parametric modelling tools, are pervasive in the work. Material intelligence, manufacturing constraints and assembly logics are key parameters in this new design space. Matter, rather than being inert, is appreciated and interrogated for its responsiveness. Early physical testing of assemblies drive digital models and decision making, countering a common critique of digital architecture's bias towards form before material.

We begin with case studies investigating the design and fabrication of complex geometries that bridge the widely recognised gap between the generation and materialisation of digital form. Menges, Schleicher & Fleischmann's Research Pavilion at the University of Stuttgart presents one strategy of material-oriented computational design where structure and space is informed by the physical behaviour of bent plywood and the constraints of their fabrication tools. The pliability of this material is further utilised at the Centre for Information Technology and Architecture, Copenhagen, to build 'soft' responsive environments. Coupled with servo motor actuation and a secondary pleated manifold it suggests that material understanding could inform the actuation of kinetic textile structures to work intelligently with changing physical load-paths. Through continual interaction between embedded micro-processing and material computation, environments saturated with sensing and actuation forge hybrid digital/analogue networks. ProtoNODE, presented by the Hyperbody Research Group, Delft, probe possible human-human, human-object and object-object relationships enabled by a responsive modular assembly. Just how small we conceive of these networks, and the potential they have not just to think but also to construct and repair themselves, is provocatively examined by Skylar Tibbits' system of mechanical logic modules for self-guided-assembly.

Where architects *(namely engineering)* may conventionally turn to other disciplines to solve problems associated with constructing complex form, a number of featured research projects are utilising robotic manufacturing techniques spearheaded by the automotive and aeronautical industries. Built works by the University of Michigan Taubman College and ETH Zurich demonstrate the latent potential for novel solutions and new opportunities to be found within generic robotic armatures. With CAD/CAM facilities now commonplace in architecture schools and open-source initiatives such as Fab@Home and RepRap gaining recognition, it is not surprising that designers are looking beyond existing fabrication technologies. A generation of confident, computationally trained and materially literate students from The Bartlett School of Architecture, Architectural Association and the Institute for Advanced Architecture of Catalonia present hacking, reformatting and reinventing fabrication processes to stimulate new building scenarios, site- and material-specific tools. The range of 'off the shelf' and custom machinery employed, and the techniques

invented throughout this publication are remarkable, but few of its authors attribute much value to the machine itself but rather to the opportunities they present. There is a common humility in their endeavours, skipping over their intimate knowledge of servo control, communication protocols and tooling parts as casually as preceding generations talked about their parallel rule or set square.

In bringing together the themes of the conference and publication it was important that, along with exploring the opportunities for innovative design, we would demonstrate how architects are offering solutions to two of the most pressing economic and sustainable issues of our time: the shortage of energy and the need to reduce carbon emissions. These designer-makers, developing their own tools, handling materials and observing fabrication in action, are acutely aware of the off-cuts, the fumes, the weight and issues of assembling their work. Efficiency and environmental impact are never far from their mind, waste is considered alongside the intended artefact. Such sensitivity is widely missing in a profession that has for so long seen the pursuit of intellectual labour as superior to that of physical labour.

From the fifteenth century to today, architects have increasingly made drawings and models, not buildings. The dominant feature of the architectural drawing's role in representing the visual before questions of material and construction is later elaborated. It is uncommon to see an architect, particularly in practice, using the drawing for its potential to act as an analogue, allowing instead for techniques and medium to infer methods of construction, material and meaning. The process and tools of representation are called into question and recalibrated by Nat Chard through an account of a series of his built drawing instruments, which operate between drawing and making, indeterminacy and precision. Enabling unpredictable deviation to be celebrated when fortuitous, tempered when necessary and fundamentally harnessed, Phil Ayres presents feedback systems between virtual models and physical prototypes as a response to his critique of predictive modelling. The imperfect transformations back and forth between digital and physical artefacts are, from one perspective, an engineering problem to be solved but, from the perspectives of a number of projects here, serendipitous and productive opportunities. Flourishing in the 'noise', Shaw and Trossell present a series of case studies ranging from the analytical to the speculative, revealing surprising new design strategies formed through their experimentation with 3D scanning tools.

Over the past decade, the practice of architecture has radically transformed through the digital acceleration and sharpening of production. New architectural languages are being constructed through the conversation between material, tool and design intent. These advances represent an opportunity for architects to relocate themselves within the design space of the construction industry, back at the heart of the process. Whether a greater role in fabrication encourages better architecture is beyond the scope of this publication but we strongly believe this volume of case studies offers a compelling range of strategies for practice and academia to reflect and build upon.

INTRODUCTION RUAIRI GLYNN

END

REFERENCES

RESEARCH PAVILION ICD/ITKE

1 Menges, A., 'Form Generation and Materialization at the Transition from Computer-aided to Computational Design', Detail, English Edn, vol. 2010, no. 04, pp. 330–35.

2 Menges, A., 'Material Information: Integrating Material Characteristics and Behavior in Computational Design for Performative Wood Construction, In:Formation', Proceeding of the 30th Conference of the Association For Computer Aided Design in Architecture (ACADIA) (New York, 28–24 October 2010), pp. 151–158.

3 Menges, A., 'Performative Wood: Integral Computational Design for Timber Construction, Reform: Building a Better Tomorrow', Proceeding of the 29th Conference of the Association For Computer Aided Design In Architecture (ACADIA) (Chicago, 21–25 October 2009), pp. 66–74.

4 Lienhard, J., S. Schleicher, J. Knippers, S. Poppinga and T. Speck, 'Form-finding of Nature Inspires Kinematics for Pliable Structures', in *Proceedings of the International Symposium of the International Association of Shell and Spatial Structures (IASS), Spatial Structures Temporary and Permanent,* ed. Q. Zhang et al. (Shanghai, 2010), p. 501.

THAW IMAGINING A SOFT TECTONICS

1 The textile is developed in collaboration with Prof. Behnam Pourdeyhimi, North Carolina State University, College of Textiles. The material is a blend of polyester and co-polyester. The co-polyester melts at a lower temperature and 'binds' the fibres together. The structure was made by carding crosslapping, followed by needle punching, and then passed through the over to partially melt some of the co-polyester. Prof. Pourdeyhimi used a very special experimental needle that densifies the web to give it density. The web is ~ 300 g/square metre.

2 'Geodetic Construction: Vickers-Wallis System Explained: Advantages of Concentrating Material. Balancing Tension Against Compression', Flight (16 January 1936), p. 67.

3 Graefe, R., 'Vladimir G. Suchov 1853–1939. Die Kunst der sparsamen Konstruktion' (Stuttgart: Deutsche Verlags-Anstalt, 1990).

4 This parametric modelling of the material performance is developed across a series of projects in CITA and has been first implemented in the research workshop 'Digital Crafting: How to Join as Part of a Cross-national Research Network': www.digitalcrafting.dk

5 The research collaboration is part of the Velux Guest Professorship with Prof. Mark Burry, Spatial Information Architecture Laboratory, RMIT, Melbourne. The project is a broad collaboration between the two research centres and includes collaboration with Prof. Mark Burry, Jane Burry, Mette Ramsgard Thomsen, Martin Tamke, Phil Ayres, Alexander Pena, Daniel Davis, Jacob Riiber Nielsen, Stig A. Nielsen, Anders Holden Deleuran, Morthen Winther and Sigurdur Ormarsson.

FABRICATING INDETERMINATE PRECISION

1 Todorov, Tzvetan, *Symbolism and Interpretation,* trans. from Marjorie Perloff, *Poetics of Indeterminacy* (Evanston: Northwestern University Press, 1999)

(FAB)BOTS CUSTOMISED ROBOTIC DEVICES FOR DESIGN & FABRICATION

1 Referring to research conducted by Behrokh Khoshnevis (University of Southern California), Rupert Soar (Loughborough University) and Gramazio & Kohler (ETH Zurich), amongst a growing number of fabrication-related courses and workshops at several universities worldwide.

2 The studios are titled 'Machinic Control 1.0' (AA) and 'Digital Tectonics RS3' (IAAC). The three projects from the AA are produced during a 12-month period of research, while the seven projects from IAAC were conceived in a period of five months. Both design studios supported the work through tutorials in programming and building customised devices using a standard CNC stepper motor control module or the open-source electronics prototyping platform Arduino, which is based on flexible, easy-to-use hardware and software. Student teams were encouraged to benefit from and contribute to a large on-line community sharing experiences with interactive devices and installations.

3 BEAM is an acronym for Biology, Electronics, Aesthetics and Mechanics. This is a term that refers to a style of robotics that primarily uses simple analogue circuits, such as comparators, instead of a microprocessor in order to produce an unusually simple design (in comparison to traditional mobile robots). BEAM robots typically consist of a set of the aforementioned analogue circuits (mimicking biological neurons), which facilitate the robot's response to its working environment.

4 Braitenberg Vehicles are conceived by the Italian-Austrian cyberneticist Valentino Braitenberg and illustrate the abilities of simple agents. The vehicles represent the simplest form of behaviour-based artificial intelligence or embodied cognition; that is, intelligent behaviour that emerges from sensorimotor interaction between the agent and its environment, without any need for an internal memory, representation of the environment or interference.

5 BOIDS is an artificial life program, developed by Craig Reynolds in 1986, which simulates the flocking behaviour of birds. As with most artificial life simulations, BOIDS is an example of emergent behaviour; that is, the complexity of BOIDS arises from the interaction of individual agents (the BOIDS, in this case) adhering to a set of simple rules.

CNCATENARY TOWARDS A DIGITAL FABRICATION METHOD FOR CATENARY SYSTEMS

1 Chak, D., M. Galbraith and A. Kilian, 'CatenaryCAD: An Architectural Design Tool' final project report for a class on computer graphics, MIT (2002)

MATTER & MAKING

1 'The 2003 Inductees', The Robot Hall of Fame Webpage, The School of Computer Science at Carnegie Mellon Universtity: www.robothalloffame.org/unimate (accessed 5 December 2010).

2 The designed wind was calculated for a reduced wind speed of 50 mph yielding a pressure of approximately 5 psf. For reference, the Safir-Simpson Hurricane Scale defines winds of 50 mph as a tropical storm.

3 A Change of State is constructed of polyurethane sheet material. The sheets were CNC profile cut into custom construction units. These units were cold bent, twisted and bolted to their neighbours to occupy the third dimension. By aggregating this system, volume was occupied in the form of a space truss spanning a full column bay.

4 Drawn Dress is an interdisciplinary project addressing the custom needs of dress design with advanced technologies such as digital body scanning and CNC fabric cutting. The designs produced during the project all hug tightly to the body as a way of testing the precision and fit, though they leave the body to enter the volumetric space of digital modeling. The seams of these dresses are truly 3D and are conceived of as volumetric objects, though implemented through 2D patterns.

5 AtmoSPHERE is a proposal for a building envelope for a factory building in Los Angeles. This proposal questions the idea that building envelopes need to be hermetic seals. Instead, when given depth, an envelope could perform closer to a sponge or the leaves

of a tree. This volumetric envelope shades the interiors, while allowing ventilation to move freely through the envelope and condition through its filtering technique.

6 This research is not obligated to EPS foam as a material, but rather volumetric materials as a larger category. While EPS foam was used for this case study, further research is taking place to engage these other volumetric materials listed.

7 The EPS foam for Periscope was sourced in Michigan, fabricated in there, and transported to Atlanta. Sourcing is Atlanta was possible; however, the fabrication facilities available to the project in Atlanta were not equipped to handle the material or the method developed. As a proposal for a larger making process, it must be clarified there is an assumption that these fabrication techniques would be local as well.

8 Stereotomy is the technique of cutting solids to specific forms and dimensions.

9 Evans, Robert, 'Drawn Stone', in *The Projective Cast: Architecture and Its Three Geometries* (Cambridge, MA: MIT, 1995), print.

10 For the stonemason, this line was not a physical object, but rather a geometric principle allowing 2D traits to describe a 3D form. The hot-wire performed as this principle in real time.

TERRA THERMA

1 See www.water-technology.net/projects/thameswater

INVESTIGATIONS IN DESIGN & FABRICATION AT HYPERBODY

1 Arduino is an open-source electronics prototyping platform, for more information please see: www.arduino.cc

2 NedCAM is a company based in the Netherlands that specializes in large-scale CNC fabrication and have worked on a number of interesting architectural projects. Its important to point out that NedCAM has been experimenting with hot-wire cutting for the roughening foam blocks that will befurther milled.

INTRODUCTION BOB SHEIL

1 See Sheil, B., 'Transgression from Drawing to Making' in *Architectural Research Quarterly* Vol. 9 Issue 1, (Cambridge University Press), pp 20-32, 26 Illustrations ISSN 1359-1355

2 See Bonwetsch, T., Gramazio, F., Kohler, M., 'R-O-B Towards a Bespoke Building Process in Sheil, R. (ed) *Manufacturing the Bespoke An AD Reader* Wiley (2012)

3 See Sheil, R., (ed), Ayres, P, Callicott, N., Sharpe, P. *55/02: A Sixteen*(makers) Monograph.* Riverside Architectural Press 2012

LARGE, COMPLEX, PERFORATED ENCLOSURES IN EXTREME ENVIRONMENTS CONTROL OF STRUCTURAL & THERMODYNAMIC BEHAVIOUR, FROM MACRO TO NANO-SCALE

1 Baker, W. F., *Stiffness Optimization Methods for Lateral Systems of Buildings: A Theoretical Basis, Electronic Computation, 21 Buildings, Towers and Tanks* (CE) (1991), pp. 269–78.

2 Almarshad, A. I., and S. Syed, 'Atmospheric Corrosion of Galvanised Steel and Aluminiumin Marine and Marine-industrial Environments in Saudi Arabia', *Materials & Corrosion,* vol. 59, no. 1. (2008).

3 Monteith, J. L., and M. H. Unsworth, *Principles of Environmental Physics,* 3rd Edn (Academic Press, 2008).

4 de Villiers, M. P., and J. van Heerden, 'Fog at Abu Dhabi International Airport', *Weather* (2007), vol. 62, no. 8, pp. 209–14.

5 Nosonovsky, M., and B. Bhushan, eds, Theme Issue 'Green Tribology', Phil. Trans. R. Soc. A. (28 October 2010), vol. 368, no. 1929.

6 Bejan, A., and S. Lorente, 'The Constructal Law of Evolution in Design and Nature', Phil. Trans. R. Soc.B (12 May 2010), vol. 365, n13th of May 2008.

7 Ibid.

FURTHER READING

CNCATENARY TOWARDS A DIGITAL FABRICATION METHOD FOR CATENARY SYSTEMS

Gramazio, F., and M. Kohler, *Digital Materiality in Architecture* (Baden: Lars Müller Publishers, 2008).

Chak, D., M. Galbraith and A. Kilian, 'CatenaryCAD: An Architectural Design Tool' final project report for a class on computer graphics, MIT (2002)

Kolarevic, B., 'Information Master Builders', in *Architecture in the Digital Age: Design and Manufacturing,* ed. Kolarevic (New York: Spon, 2003)

DESIGN FOR POTENTIAL LARGE-SCALE ADDITIVE FABRICATION FREE-FORM CONSTRUCTION

Bernaerdt, S., K. Van Hauwaert and X. De Kestelier, 'Large-scale Rapid Manufacturing for Construction Industry: The Architecture of a New Design Environment', unpublished dissertation at the Department of Architecture and Urban Design, University Ghent (2009)

De Kestelier, X., and B. Peters, 'Rapid Prototyping and Rapid Manufacturing at Foster+Partners', Proceeding of the ACADIA 2008 Conference Minneapolis: Proceedings of the 28th Annual Conference of the Association for Computer Aided Design in Architecture(ACADIA) (2008)

De Kestelier, X., and R. A. Buswell, 'A Digital Design Environment for Large-scale Additive Fabrication', Proceeding of Arcadia 2009, reForm conference (Chicago, 22 October 2009)

Dini, E., R. Nannini and M. Chiarugi, 'Method and Device for Building Automatically Conglomerate Structures', WO Patent WO/2006/100,556 (2006)

Gardiner, J., 'Sustainability and Construction-Scale Rapid Manufacturing: Opportunities for Architecture and the Construction Industry' Proceeding of RAPID 2009 Conference (17 June 2009)

Khoshnevis, B., D. Hwang, K. T. Yao and Z. Yeh, 'Mega-scale Fabrication by Contour Crafting', *International Journal of Industrial and Systems Engineering,* (2006), no. 1, pp. 301–20

Dosher, M., 'Modelling in a Digital Dimension', Designbuild-network: www.designbuild-network.com/features/feature75564 (accessed 1 December 2010)

Wholers, T., *Rapid Prototyping, Tooling and Manufacturing: State of the Industry* (Colorado: Wohlers Associates, 2010)

END NOTES

of a tree. This volumetric envelope shades the interiors, while allowing ventilation to move freely through the envelope and condition through its filtering technique.

6 This research is not obligated to EPS foam as a material, but rather volumetric materials as a larger category. While EPS foam was used for this case study, further research is taking place to engage these other volumetric materials listed.

7 The EPS foam for Periscope was sourced in Michigan, fabricated in there, and transported to Atlanta. Sourcing is Atlanta was possible; however, the fabrication facilities available to the project in Atlanta were not equipped to handle the material or the method developed. As a proposal for a larger making process, it must be clarified there is an assumption that these fabrication techniques would be local as well.

8 Stereotomy is the technique of cutting solids to specific forms and dimensions.

9 Evans, Robert, 'Drawn Stone', in *The Projective Cast: Architecture and Its Three Geometries* (Cambridge, MA: MIT, 1995), print.

10 For the stonemason, this line was not a physical object, but rather a geometric principle allowing 2D traits to describe a 3D form. The hot-wire performed as this principle in real time.

TERRA THERMA

1 See www.water-technology.net/projects/thameswater

INVESTIGATIONS IN DESIGN & FABRICATION AT HYPERBODY

1 Arduino is an open-source electronics prototyping platform, for more information please see: www.arduino.cc

2 NedCAM is a company based in the Netherlands that specializes in large-scale CNC fabrication and have worked on a number of interesting architectural projects. Its important to point out that NedCAM has been experimenting with hot-wire cutting for the roughening foam blocks that will befurther milled.

INTRODUCTION BOB SHEIL

1 See Sheil, B., 'Transgression from Drawing to Making' in *Architectural Research Quarterly* Vol. 9 Issue 1, (Cambridge University Press), pp 20-32, 26 Illustrations ISSN 1359-1355

2 See Bonwetsch, T., Gramazio, F., Kohler, M., 'R-O-B Towards a Bespoke Building Process in Sheil, R. (ed) *Manufacturing the Bespoke An AD Reader* Wiley (2012)

3 See Sheil, R., (ed), Ayres, P, Callicott, N., Sharpe, P. *55/02: A Sixteen*(makers) Monograph.* Riverside Architectural Press 2012

LARGE, COMPLEX, PERFORATED ENCLOSURES IN EXTREME ENVIRONMENTS CONTROL OF STRUCTURAL & THERMODYNAMIC BEHAVIOUR, FROM MACRO TO NANO-SCALE

1 Baker, W. F., *Stiffness Optimization Methods for Lateral Systems of Buildings: A Theoretical Basis, Electronic Computation, 21 Buildings, Towers and Tanks* (CE) (1991), pp. 269–78.

2 Almarshad, A. I., and S. Syed, 'Atmospheric Corrosion of Galvanised Steel and Aluminiumin Marine and Marine-industrial Environments in Saudi Arabia', *Materials & Corrosion,* vol. 59, no. 1. (2008).

3 Monteith, J. L., and M. H. Unsworth, *Principles of Environmental Physics,* 3rd Edn (Academic Press, 2008).

4 de Villiers, M. P., and J. van Heerden, 'Fog at Abu Dhabi International Airport', *Weather* (2007), vol. 62, no. 8, pp. 209–14.

5 Nosonovsky, M., and B. Bhushan, eds, Theme Issue 'Green Tribology', Phil. Trans. R. Soc. A. (28 October 2010), vol. 368, no. 1929.

6 Bejan, A., and S. Lorente, 'The Constructal Law of Evolution in Design and Nature', Phil. Trans. R. Soc.B (12 May 2010), vol. 365, n13th of May 2008.

7 Ibid.

FURTHER READING

CNCATENARY TOWARDS A DIGITAL FABRICATION METHOD FOR CATENARY SYSTEMS

Gramazio, F., and M. Kohler, *Digital Materiality in Architecture* (Baden: Lars Müller Publishers, 2008).

Chak, D., M. Galbraith and A. Kilian, 'CatenaryCAD: An Architectural Design Tool' final project report for a class on computer graphics, MIT (2002)

Kolarevic, B., 'Information Master Builders', in *Architecture in the Digital Age: Design and Manufacturing,* ed. Kolarevic (New York: Spon, 2003)

DESIGN FOR POTENTIAL LARGE-SCALE ADDITIVE FABRICATION FREE-FORM CONSTRUCTION

Bernaerdt, S., K. Van Hauwaert and X. De Kestelier, 'Large-scale Rapid Manufacturing for Construction Industry: The Architecture of a New Design Environment', unpublished dissertation at the Department of Architecture and Urban Design, University Ghent (2009)

De Kestelier, X., and B. Peters, 'Rapid Prototyping and Rapid Manufacturing at Foster+Partners', Proceeding of the ACADIA 2008 Conference Minneapolis: Proceedings of the 28th Annual Conference of the Association for Computer Aided Design in Architecture(ACADIA) (2008)

De Kestelier, X., and R. A. Buswell, 'A Digital Design Environment for Large-scale Additive Fabrication', Proceeding of Arcadia 2009, reForm conference (Chicago, 22 October 2009)

Dini, E., R. Nannini and M. Chiarugi, 'Method and Device for Building Automatically Conglomerate Structures', WO Patent WO/2006/100,556 (2006)

Gardiner, J., 'Sustainability and Construction-Scale Rapid Manufacturing: Opportunities for Architecture and the Construction Industry' Proceeding of RAPID 2009 Conference (17 June 2009)

Khoshnevis, B., D. Hwang, K. T. Yao and Z. Yeh, 'Mega-scale Fabrication by Contour Crafting', *International Journal of Industrial and Systems Engineering,* (2006), no. 1, pp. 301–20

Dosher, M., 'Modelling in a Digital Dimension', Designbuild-network: www.designbuild-network.com/features/feature75564 (accessed 1 December 2010)

Wholers, T., *Rapid Prototyping, Tooling and Manufacturing: State of the Industry* (Colorado: Wohlers Associates, 2010)

END NOTES

AUTHORS/ ACKNOWLEDGEMENTS/ PROJECT CREDITS

RESEARCH PAVILION ICD/ITKE

AUTHORS
Achim Menges (Institute for Computational Design/ ICD), Simon Schleicher (Institute of Building Structures and Structural Design/ITKE, University of Stuttgart, Germany) and Moritz Fleischmann (Institute for Computational Design/ICD).

ACKNOWLEDGEMENTS
The Research Pavilion was a collaborative project of the Institute for Computational Design (Prof. Achim Menges) and the Institute of Building Structures and Structural Design (Prof. Jan Knippers) at Stuttgart University, made possible by the generous support of a number of sponsors including OCHS GmbH, KUKA Roboter GmbH, Leitz GmbH & Co. KG, A. WÖLM BAU GmbH, ESCAD Systemtechnik GmbH and the Ministerium für Ländlichen Raum, Ernährung und Verbraucherschutz Landesbetrieb Forst Baden-Württemberg (ForstBW).

The project team included Andreas Eisenhardt, Manuel Vollrath, Kristine Wächter & Thomas Irowetz, Oliver David Krieg, Ádmir Mahmutovic, Peter Meschendörfer, Leopold Möhler, Michael Pelzer and Konrad Zerbe.

Responsible for the scientific development were Moritz Fleischmann (project management), Simon Schleicher (project management), Christopher Robeller (detailing/construction management), Julian Lienhard (structural design), Diana D'Souza (structural design) and Karola Dierichs (documentation).

PROJECT CREDITS
Institution: University of Stuttgart. Department: Faculty of Architecture. Institutes: Institute for Computational Design (ICD), Prof. Achim Menges, and Institute of Building Structures and Structural Design (ITKE), Prof. Jan Knippers. Project Team (Concept and Realisation): Andreas Eisenhardt, Manuel Vollrath, Kristine Wächter and Thomas Irowetz, Oliver David Krieg, Ádmir Mahmutovic, Peter Meschendörfer, Leopold Möhler, Michael Pelzer and Konrad Zerbe. Scientific Development: Moritz Fleischmann (project management), Simon Schleicher (project management), Christopher Robeller (detailing / construction management), Julian Lienhard (structural design), Diana D'Souza (structural design), Karola Dierichs (documentation).

LINKS
http://icd.uni-stuttgart.de/?p=4458
www.itke.uni-stuttgart.de/de/forschung/Forschungspavillon.htm

CONTACT
mail@icd.uni-stuttgart.de (ICD)
info@itke.uni-stuttgart.de (ITKE)

THAW IMAGINING A SOFT TECTONICS

AUTHORS
Mette Ramsgard Thomsen, Karin Bech and Martin Tamke, Centre for IT and Architecture, Royal Danish Academy of Fine Arts, School of Architecture.

ACKNOWLEDGEMENTS
Thaw was exhibited as part of the digital material exhibition at R.O.M Gallery for Art and Architecture, Oslo, in May 2010. The exhibition was kindly supported by the Nordic Culture Foundation and Henrik de Miniassen, director of R.O.M. Thaw was further developed as a larger-scale installation for the Lisbon Architecture Triennale as a 10-metre-high installation Thicket.

Thaw was further supported through the collaboration with Behnam Pourdeyhimi, NC State University College of Textiles.

(FAB)BOTS CUSTOMISED ROBOTIC DEVICES FOR DESIGN & FABRICATION

Design Studio: 'Machinic Control 1.0': Tutors: Marta Malé-Alemany, Jeroen van Ameijde. Architectural Association School of Architecture, Design Research Lab (DRL) Graduate Programme (2009–10). Projects: DIGITAL VERNACULAR: Shankara S. Kothapuram, Mei-ling Lin, Ling Han, Jiawei Song. FIBR(H)OUS(E): Amrita Deshpande, Saahil Parikh, Akhil Laddha. FLUID CAST: Ena Lloret, Maria Eugenia. Villafañe, Jaime De Miguel, Catalina Pollak. Design Studio: 'Digital Tectonics RS3', Tutors Marta Malé-Alemany, Victor Viña, César Cruz Cazares (assistant), Lluís Fraguada (collaborator). Institute of Advanced Architecture of Catalonia (IAAC), Master in Advanced Architecture (2009–10). Projects: SANDBOT: Joel Letkemann, Viraj Kataria, Fabio Lopez. HELIOBOT: Felipe Pecegueiro, Jorge Orozco, Kfir Gluzberg. FAB [A]THING: Jun Huang, Jessica Lai, Asim Hameed. DREAMWEAVER: Melat Assefa, Brian Peters, Joao Albuquerque. NGPS: Ali Basbous, Miquel Lloveras. PNEUMORPHOSYS: Natalija Boljsakov, Brian Miller, Carlos Naranjo. MIMICRY: Mia Gorretti Layco, Georgia Kotsari, Tomasz Starczewski. Exhibition: (FAB)BOTS, Customized robotic devices for design and fabrication, 16 June to 12 September 2010, Disseny Hub Barcelona (DHUB). Curator: Marta Malé-Alemany. Coordination: Catalina Pollak.

LOGIC MATTER

Logic Matter was made possible by the support, inspiration and critique from collaborations at MIT with Erik Demaine, Patrick Winston, Terry Knight and Neil Gershenfeld.

CNCATENARY TOWARDS A DIGITAL FABRICATION METHOD FOR CATENARY SYSTEMS

This research was realised as part of the Master of Science in Adaptive Architecture and Computation at the University of London Bartlett School of Graduate Studies. It was carried out at the facilities and workshops of The Bartlett School of Architecture and under the supervision of my tutors, Ruairi Glynn and Marilena Skavara.

SCANLAB

FARO Europe
Pointools
CEGE@ucl
Slade@ucl

FREE-FORM METAL INFLATION & THE PERSISTENT MODEL

Anders Holden Deleuran (research assistant, CITA) for his persistent and skilled attempts at modelling the metal inflation process using Autodesk Maya. My colleagues at the Centre for IT and Architecture (CITA) and Institute 4, Kunstakademiets Arkitektskole, for their continued encouragement and support of this work.

Persistent Model #1 was an exhibit in the show entitled *digital.material* which showcased four recent works by CITA. The exhibition ran from 23 April to 23 May 2010 at the ROM Gallery, Oslo.

MATTER & MAKING

PERISCOPE FOAM TOWER

AUTHORS
Brandon Clifford and Wes McGee

PROJECT CREDITS
Design Team: Matter Design – Brandon Clifford, Wesley McGee. In collaboration with Supermanoeuvre – Dave Pigram. Structural: Simpson Gumpertz&Heger – Matthew Johnson. Build Team: Matter Design – Brandon Clifford, Wesley McGee, Johanna Lobdell, Deniz McGee, Kris Walters, Maciej Kaczynski. Rigging: Boutte Tree – TiersonBoutte. Fabrication: University of Michigan Taubman College of Architecture and Urban Planning.

WAVE PAVILION

Designer/Fabricator: macdowell.tomova. Consultants: Wes McGee, Matter Design; Dave Pigram, Supermanoeuvre.

BENT

Kendra Byrne and Nick Rebeck: www.b-e-n-t.com

Special thanks to faculty advisors David Pigram and Wes McGee.

MATERIAL ANIMATION A NEW INTERFACE TO CUSTOM FABRICATION

Work developed on robotic folding methods was done in collaboration with Robofold Ltd., Gregory Epps. Field Condition is supported by the University of Kentucky College of Design – School of Architecture, College of Engineering – Dept. of Computer and Electrical Engineering, and the Institute of Sustainable Manufacturing. The team for Field Condition is Anton Bakerjian and Ian McHone.

MINIMAL COMPLEXITY

The Minimal Complexity prototype was developed during the Certificate of Advanced Architectural Research Postgraduate Course at The Bartlett,UCL, between 2009 and 2010, and it has taken part in 'Constructing Realities', the final exhibition of the Course's research work between July and October 2010.

The theoretical paper 'Minimal Surfaces as Self-Organizing Systems' describing the computational framework for generating the final prototype was developed as part of the MSc. Adaptive Architecture and Computation Course at The Bartlett, UCL, 2009, and has been presented at ACADIA Conference, in New York, in October 2010.

The Minimal Complexity structure winner of the TEX-FAB REPEAT Digital Fabrication Competition was built in Houston, Texas, in February 2011.

ACKNOWLEDGMENTS
Ruairi Glynn, Prof. Stephen Gage, Sean Hanna, Alasdair Turner, The Bartlett School of Architecture, UCL. Brad Bell, Kevin Patrick McClellan, Andrew Vrana, TEX-FAB Digital Fabrication Alliance.

INVESTIGATIONS IN DESIGN & FABRICATION AT HYPERBODY

PROTODECK

AUTHORS
Marco Verde Eng, MArch, MarkDavid Hosale, Ph.D.

PROJECT CREDITS
Property Developer: Hyperbody | TU Delft. Direction: Prof. ir. Kas Oosterhuis. protoDECK system development and manufacturing engineering: Marco Verde Eng, MArch. protoNODE system development and manufacturing engineering: Dr MarkDavid Hosale. Digital Fabrication: NEDCAM, HYPERBODY CNC DIVISION. Project Sponsor: Missler Italy – TopSolid

PROTOSPACE 4 MOCK-UP

AUTHOR
Jelle Feringa, PhD candidate, co-founder EZCT Architecture & Design Research

PROJECT CREDITS
Design of the protoSPACE 4 pavilion was completed in the context of the MSC2 spring 2009 design studio. Hot-wire manufacturing: Jelle Feringa & Haiko Dragstra (Komplot Mechanics). Components connections: Owen Slootweg. Final Assembly: Owen Slootweg & Chris Kievid & Jelle Feringa. Project managment: Chris Kievid.

PROTOTYPE FOR A SPATIALISED INSTRUMENT

This project would not have been possible without generous help from Bob Sheil, Emmanuel Vercruysse, Paul Bavister, Abi Abdolwahabi, Bim Burton, Martin Avery, Christian Nold, Jon Mercer, Justin Goodyear, Fin Fraser, Javiera Izquierdo Ieiva, Ric Lipson and Lucy Voice. Also thanks to the Centre for Cretive Collaboration, Brian Condon, Thias Martin and Neil Gregory.

www.mishasmith.com

VILLA NURBS

City: Empuriabrava. Country: Spain. Construction: started 2003. Office: Cloud 9 (Barcelona, Spain; est. 1997) Architect: Enric Ruiz Geli. Collaborators: Felix Fassbinder (Project Architect), Jordi Fernández Río (Project Architect). Arquitectos Técnicos: Daniel Benito Pò (Architect), Xavier Badia (Architect), Agustí Mallol (Architect), Víctor Llanos (Collaborator [office]), Miguel Carreiro (Collaborator [office]), Emmanuel Ruffo (Collaborator [office]), Rosa Duque (Collaborator [office]), André Macedo (Collaborator [office]), Ura Carvalho (Collaborator [office]), Hye Young Yu (Collaborator [office]), Marta Yebra (Collaborator [office]), Mae Durant (Collaborator [office]), Angelina Pinto (Collaborator [office]), Randall Holl (Collaborator [office]), William Arbizu (Collaborator [office]), Max Zinnecker (Collaborator [office]), Laia Jutgla (Collaborator [office]), Manel Soler (Collaborator [office]), Megan Kelly-Sweeney (Collaborator [office]), Alessandra Faticanti (Collaborator [office]), Susanne Bodach (Collaborator [office]), André Brosel (Collaborator [office]), Konrad Hofmann (Collaborator [office]), Nora Graw (Collaborator [office]), Cricursa/Vicky Colombet (Glas Manufaturer), Toni Cumella Ceramic Manufacturer), Frederic Amat (Ceramic Artist), Industrias de la Fusta (IFV) (Corian Manufacturer), Covertex (ETFE Manufacturer), BOMA SL (Engineering), Obres i Construccions Joan Fustè (Construction), Diorama (Wood), Calderería Delgado (Steel Framework), Ramón Presta (Hydraulics), Industrias BEC (Tensile Structures), Aiterm, PGI, Reindesa (Installations), Aislater, Inoxcolor (Installations), Estudi Ramon Folch (Construction), Emiliana Desigestudio (Graphic Design), BAF (Audiovisuals), Led's Go (Illumination). Client (Private): Family Emilio Gallego. Programme: housing.

C-STONE & C-BENCH

This project is dedicated to Christel Vandewaerde (4 December 1963 – 18 December 2010).

GALAXY SOHO LARGE-SCALE CLADDING CONSTRUCTION IN CHINA

Client: SOHO China Ltd., Beijing, China. Architect: ZAHA HADID ARCHITECTS. Design: Zaha Hadid with Patrik Schumacher. Project Associate: Cristiano Ceccato. Project Director: Satoshi Ohashi. Project Architect: Yoshi Uchiyama. Project Manager: Raymond Lau. Project Team: Stephan Wurster, Michael Hill, Samer Chamoun, Eugene Leung, Rita Lee, Lillie Liu, Rolando Rodriguez-Leal, Wen Tao, Tom Wuenschmann, Seung-ho Yeo, Shuojiong Zhang, Michael Grau, Shu Hashimoto, Shao-Wei Huang, Chikara Inamura, Lydia Kim, Yasuko Kobayashi, Wang Lin, Yereem Park, Christoph Klemmt, Dorian Bybee, Kyla Farrell, John Klein. Local design institute:

BIAD (Beijing Institute of Architecture and Design), Beijing. Facade engineer: KT Kighton Ltd., Shanghai. Timeframe: 2008–12. Programme: Mixed-Use Commercial & Retail Complex, Shell & Core Fit-Out. GFA: 360,000m2 + 150,000m2 Below Grade. Site Area: 50,000m2. Height: 67 metres = 16 Floors Above Grade.

MEDIA-ICT

City: Barcelona. Country: Spain. Completed: January 2010 (started 2005). Office: Cloud 9 (Barcelona, Spain; est. 1997)

Architect: Enric Ruiz Geli. Collaborators: Josep María Forteza (Building advising), Agustí Obiol (Structural engineering), David Tusset (Engineering), Hector Yuste (Project management), Joan Buj Cotes (Construction), Carlos Siscart González (Construction), Ben Morris (Construction), Lluis Renom (Construction), Edouard Cabay (Architect), Javier Pérez Contonente (Architect), Francesco Ducato (Architect), Felix Fassbinder (Architect), Nora Graw (Architect), Konrad Hofmann (Architect), Victor Llanos (Architect), Max Zinnecker (Architect), Marta Arranz (Collaborator [office]), Ruben Alonso (Collaborator [office]), Luis Borunda (Collaborator [office]), Marta Banach (Collaborator [office]), Daniel Corsi (Collaborator [office]), Cristina Guadalupe (Collaborator [office]), Albert Lopez (Collaborator [office]), Mireia Luzarraga (Collaborator [office]), Patricio Levy (Collaborator [office]), Alex Muiño (Collaborator [office]), Beatriz Minguez (Collaborator [office]), Veronica Mansilla (Collaborator [office]), Federico Ortiz (Collaborator [office]), Mireia Pallarès (Collaborator [office]), Marisol Verges (Collaborator [office]), Hale YoungBlood (Collaborator [office]), Pep Bou (Art), André Macedo (Design). Client (Public): Consorci de la Zona Franca and 22@. Programme: Office.

THE SPHERE GENERATE, FABRICATE, CALCULATE

The authors would like to thank Oliver Drawer and Arnold AG for the successful collaboration during planning and construction. Their commitment is visible in the quality of the finished object. We would also like to thank Giulio Castegini , the project manager from Mario Bellini Associati S.r.l. for his untiring dedication to achieving the maximum quality.

WAVED WOODEN WALL

Kilden Performing Arts Center, Kristiansand, Norway. Architect: ALA Arkitekter AS, Helsinki, Finland. General Contractor: AF Gruppen AS, Oslo, Norway. Timber Facade Contractor: Trebyggeriet SA, Hornnes, Norway. FaCade Cladding, CNC-Fabrication: Risør Trebåtbyggeri AS, Risør, Norway. Facade Structure, CNC-Fabrication: Blumer-Lehmann AG, Gossau, Switzerland. Façade Engineering: SJB Kempter-Fitze, Eschenbach, Switzerland. Consulting, Digital Planning: designtoproduction GmbH, Erlenbach/ Zurich, Switzerland.

LOUVRE ABU DHABI 1:33 LIGHT-TEST PROTOTYPE

Construction of the 1:33 prototype has been a cooperation between: 1:One | Computational Geometry (programming), George Ackermann GmbH (manufacturing & assembly) and Honkahe Interior+Furniture (modelmaking and consulting).

PHOTO CREDITS

RESEARCH PAVILION ICD/ITKE

A. Menges, 2010: 1, 7; C. Robeller/S. Schleicher, 2010: 2, 3; A. Eisenhardt/M. Vollrath/K. Wächter/S. Schleicher, 2010: 4; A. Lautenschlager, 2010: 5; A. Eisenhardt/M. Vollrath/K. Wächter, 2010: 6,9; S. Schleicher, 2010: 8.

UNIKABETON PROTOTYPE

All images © Per Dombernowsky and Asbjørn Søndergaard 2010.

FREE-FORM METAL INFLATION & THE PERSISTENT MODEL

Anders Ingvartsen: 1, 3; Anders Holden Deleuran, CITA: 5.

MATTER & MAKING

PERISCOPE FOAM TOWER

Matter Design, 2010: 1, 2, 4, 5, 6, 7; FABLab University of Michigan Taubman College of Architecture and Urban Planning, 2010: 3.

BENT

All images: Kendra Byrne and Nick Rebeck.

MATERIAL ANIMATION A NEW INTERFACE TO CUSTOM FABRICATION

Greg Epps, 2010: 1; Nick Puckett, 2010: 3.

INVESTIGATIONS IN DESIGN & FABRICATION AT HYPERBODY

Jelle Feringa, 2010: 1, 6, 7, 8, 9, 10; MarkDavid Hosale, 2010: 2; MarkDavid Hosale/ Marco Verde, 2010: 3; Jan Jacobs, 2009: 4; Marco Verde, 2010: 5.

KOHLER/KARA

All images: Gramazio & Kohler, Architecture and Digital Fabrication, ETH Zürich.

BEESLEY/STACEY

All photos: ©PBAi/Pierre Charron.

OXMAN/HANNA

All photos: Neri Oxman.

VILLA NURBS

Photo by Luis Ros © Cloud9: 1, 2, 4; Victor Llanos © Cloud9: 3, 5, 6, 7.

GALAXY SOHO LARGE-SCALE CLADDING CONSTRUCTION IN CHINA

All images © Zaha Hadid Architects.

MEDIA-ICT

Photo by José Miguel Hernandez © Cloud9: 1, 9; Photo by Luis Ros © Cloud9, La Chula: 5; Photo by Iwan Baan, Cloud9: 3, 11, 12; Photo by Luis Ros © Cloud9: 2, 13.

THE SPHERE GENERATE, CALCULATE, FABRICATE

All images © Bollinger + Grohmann Ingenieure, 2010.

THE RICHMOND SPEED SKATING OVAL ROOF

Fast + Epp Engineers: 1; StructureCraft Builders: 2–8.

THREE PROJECTS
A COMPARITIVE STUDY

Amanda Levete Architects: 1, 3, 4, 5, 6, 7, 8, 10; Edmund Sumner: 2; Leo Torri for DuPontTM Corian®: 9; © Meinhardt Façade Technologies: 11.

MULTI-SPHERICAL MIRRORED SCULPTURE

M. Hess photography: 1; Arup photography: 2, 3, 4, 7.

MÉDIACITÉ

Photo by Paul Madden, 2009: 1, 4; Image by Ron Arad Architects, 2007: 2, 5; Photo by Yvés L'Hermite, 2008: 3, 7; Photo by JL Deru, 2008: 6; Photo by Marc Detiffe, 2010: 8.

RADIOLARIA PAVILION

Credit: Blueprint, 2009: 1; Credit: Shiro Studio: 2, 4; Credit: D-Shape, 2009: 3, 5, 6.

WAVED WOODEN WALL

1, 2 © Trebyggeriet; 3, 4, 5 © designtoproduction.

Edited by Ruairi Glynn and Bob Sheil
Assistant editor: Marilena Skavara
Copy editor: Blanche Craig
Book design: Emily Chicken

Published by Riverside Architectural Press.
www.riversidearchitecturalpress.com

Second edition.

Library and Archives Canada Cataloguing in Publication

Fabricate : making digital architecture / edited by Ruairi Glynn and Bob Sheil ; foreword by Alan Penn and Robert Aish. – 2nd ed.

Based on papers presented at the Conference Fabricate, held at the Bartlett School of Architecture, London, from April 15–16, 2011.

Includes bibliographical references.
ISBN 978-1-926724-18-8

1. Architectural design–Data processing.
2. Architecture–Computer-aided design.
3. Architecture, Modern–21st century.
I. Glynn, Ruairi II. Sheil, Bob

NA2728.
F32 2012 721.0285
C2012-906160-3

Fabricate: Making Digital Architecture is set in Futura and Absara and is printed by Regal Printing in Hong Kong.