DIGITAL CRAFTING

A NETWORK ON COMPUTATION AND CRAFT IN ARCHITECTURE, ENGINEERING AND DESIGN

RESEARCH 2009-2011
# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>p.2</td>
</tr>
<tr>
<td>Context</td>
<td>p.6</td>
</tr>
<tr>
<td>Workshop method</td>
<td>p.10</td>
</tr>
<tr>
<td><strong>Workshop 1</strong></td>
<td>p.15</td>
</tr>
<tr>
<td>Parametric Design: Encoded behaviour</td>
<td></td>
</tr>
<tr>
<td><strong>Workshop 2</strong></td>
<td>p.29</td>
</tr>
<tr>
<td>Wood Construction: How to join</td>
<td></td>
</tr>
<tr>
<td><strong>Workshop 3</strong></td>
<td>p.45</td>
</tr>
<tr>
<td>CNC Concrete: How to mould</td>
<td></td>
</tr>
<tr>
<td><strong>Symposium 1</strong></td>
<td>p.61</td>
</tr>
<tr>
<td>Computation and Craft</td>
<td></td>
</tr>
<tr>
<td><strong>Workshop 4</strong></td>
<td>p.71</td>
</tr>
<tr>
<td>Generative Logics: How to grow</td>
<td></td>
</tr>
<tr>
<td><strong>Workshop 5</strong></td>
<td>p.89</td>
</tr>
<tr>
<td>Textile logic</td>
<td></td>
</tr>
<tr>
<td><strong>Symposium 2</strong></td>
<td>p.103</td>
</tr>
<tr>
<td>Consequences</td>
<td></td>
</tr>
<tr>
<td>Network Participants</td>
<td>p.111</td>
</tr>
<tr>
<td>Picture Credits</td>
<td>p.124</td>
</tr>
</tbody>
</table>


The following publication reports on the international research network ‘Digital Crafting’ organised in the period 2009-11. The research network investigated how new digital production methods are instigating profound changes in the design and building of architecture. Developing the term Digital Crafting, the network examined how the maturing of interfaces between the design space of the architect and the production space of the manufacturer is leading to the shaping of a new material practice in architecture.

The key aim for the network was to consolidate the existing research within the area of Digital Crafting and allow for research exchanges and the formation of a solid collaborative environment. The network combined hands-on experimentation with discussion of the broader theoretical and historical frameworks in order to:

- Generate shared understanding of key research questions, techniques and technologies between network partners and consolidate shared language and terminology
- Develop and expand the theoretical and practical knowledge and know-how of the network focusing on the relation between structural organisation, material properties and digital and analogue techniques

The aim for this publication is to act as an extended catalogue and durable record introducing the guiding research questions, techniques and technologies. Presenting the wide variety of activities in the network, the publication traces the five research workshops-seminars as well as the two symposia that make up the core of the research activities. By showcasing the events through direct reporting and interviews with key guests and speakers, it is our aim to demonstrate the breadth of the research topic and the many ways in which digital crafting challenges the practices of design, architecture and engineering.

The network is cross-disciplinary, bringing together researchers and practitioners from the fields of architecture, design, engineering and manufacturing. With a strong international focus, our aim was to provide a platform in which
Dermoid, CITTA, SIAC
Photo: Anders Ingvartsen
the disciplines could discuss the fundamental conceptual as well as technological changes that are taking place within their practice. Through active knowledge sharing it was our aim to forge an environment for a shared critical reflection of the field while simultaneously fostering new alliances and collaborations.

Overall the network has been a success. In the two years of the running of the Digital Crafting network it has been greatly expanded both nationally and internationally, with participants from practice and research. The network has established new and strong relations between its partners and fostered a robust understanding of the mutual knowledge fields, techniques and technologies. This publication also acts as a record the network participants creating a directory of contacts that we hope will support the further development of collaborations.

The network was organised by Mette Ramsgaard Thomsen and Martin Tamke, of CITA (Centre for IT and Architecture) and Claus Peder Pedersen of Aarhus School of Architecture. We would like to thank our host institutions, Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation, School of Architecture and Aarhus School of Architecture. We also thank the hosts of the Digital Crafting network activities: Danish Technological Institute and Kolding School of Design. The network was made possible through the support of a Danish Council for Independent Research, Humanities research grant.

The workshop reports and evaluation as well as the interviews with invited presenters were completed by Terri Peters, Aarhus School of Architecture.

Mette Ramsgaard Thomsen, Martin Tamke and Claus Peder Pedersen, February 2012.
DIGITAL TOOLS AND MATERIAL PRACTICE

The digitisation of manufacturing tools has radically changed production. Where Computer Numerical Controlled machinery [CNC] has introduced a higher level of precision, consistency and quality as well as considerable time efficiency and the ability to deal with high levels of complexity and variance, it has also introduced a new category of tools that profoundly change the way we understand and perform manufacturing. The last 15 years has seen the introduction of a shared digital platform creating new interfaces between design, performance analysis and fabrication. The increased focus on digitally defined work processes has enabled ‘file-to-factory’ technologies in which information is passed directly from design to fabrication. New programmable design software allows for the parametric control of the design solutions giving designers, architects and engineers the possibility to develop and manage mass-customised solutions of highly specified elements.

Where this technological shift can be understood as the development and optimisation of the processes of building, it also presents new formal as well as tectonic challenges. These digital tools allow us as architects, designers and engineers to reconsider our conceptual as well as material practices. The focus of the Digital Crafting research network has been to investigate and define design concepts that emerge from this new technological platform.

PROGRAMMING AS A DESIGN TOOL

By introducing programming as a design tool, a new computational logic becomes part of the architectural design territory, presenting design concepts such as generative processes of form-finding and system self-organisation. These concepts present new morphological perspectives that challenge how we conceive space and how we engage with the processes that make up design practice.

MATERIAL THINKING AS A DESIGN DRIVER

Furthermore digital fabrication shifts material thinking into the core of design intention presenting new structural and tectonic potentials. Creating continuity between the descriptive practices of design and the material practice of
fabrication, digital crafting shifts manufacture from a practice-based knowledge residing with the craftsman, to an integrated practice that interfaces with all the different disciplines in the design chain. Rather than perceiving the material realisation of design objects or buildings as something that takes place after design, planning and optimisation, these processes shift crafting to a much more central role questioning how design interfaces with material thinking.
INTRODUCING THE CONCEPT OF MATERIAL PERFORMANCE

Digital fabrication necessitates good understanding of the crafts traditions. To design well for digital fabrication means to understand how the traditions for material manipulation, from fabrication to assembly, can be encoded into the design space. This leads to a particular interest in material performance. Crafts traditions rely on the understanding of material behaviour. To manipulate a material, is to understand and control its inherent malleability. The forming of a new digital-material design practice therefore suggests a new active material understanding. Here, active load forces are calibrated in time using complex tools for simulation and analysis allowing them to be fed back into the design process.

THE ARCHITECT AS MATERIAL DESIGNER

Finally digital fabrication also challenges the scale of the material address. Introducing coding into the design space allows architects and designers to create material specifications with extreme degrees of detail. This presents a new potential for material thinking as architects and designers become able to engage with direct material production. Rather than understanding building materials as standardised and pre-fabricated, this new perspective of highly specified material descriptions allows the manipulation of material performance through design specification. By introducing concepts of graded materials that vary material intensity or composition in direct response to their contextual or programmatic site, the material culture of industrialisation is fundamentally questioned. The Digital Crafting network has aimed to investigate this territory of thinking. Bringing together the technological and conceptual challenges that these developments impose on the traditions of architecture, design and engineering, our aim has been to question the new design ideas that they present.

The network asked what happens as the encoded and the material become part of architectural design practice and what are the material, structural and morphological potentials of this new practice?

Mette Ramsgaard Thomsen, 2012
The network activities were structured around five workshop-seminar events. The workshop-seminars focussed on specific digital-material practices that have been defining for contemporary digital design practice. The five workshop-seminars ask how traditional material techniques are challenged through digital fabrication. By querying new perspectives for the practices of timber construction (how to join), concrete casting (how to mould) and textile fabrication (how to brace) as well as their associated design paradigms parametric design (how to encode) and generative design (how to grow), the workshop-seminars gave detailed insight into selected techniques and technologies while opening up for discussion further theoretical, technical and practical consequences.

The workshop-seminars were structured as three-day events, each taking place at different institutions within the network. In each event the first two days were held as hands-on workshops where invited workshop guests introduced and led participants through a given technique. This allowed for direct engagement with techniques and technologies and insight into the particular interfaces between digital and material tools. The two-day workshops were followed by seminars that critically reflected on the given research subject. By inviting researchers and practitioners from leading academic institutions and practices, the workshop-seminar topics were given further perspective, expanding upon the research questions.

The workshop-seminars were kept deliberately small in size inviting around 20-25 participants in each workshop and around 40-60 in each seminar. This allowed the workshop-seminars to be straightforward with frank discussions of the perspectives and limitations of given topics. The intimate environment allowed participants to get to know each other and forge lasting connections. The invitation of external workshop-guests and seminar speakers further expanded the network with many participants joining later network events.
DIGITAL CRAFTING WORKSHOP-SEMINAR EVENTS

Workshop-seminar 1 (08.-10.02.2010)
  – Workshop: Parametric Design: how to encode
  – Seminar: The aware model

Workshop-seminar 2 (29.-31.03.2010)
  – Workshop: Wood construction: how to join
  – Seminar: The tectonics of the joint

Workshop-seminar 3 (18.-19.08.2010)
  – Workshop: Concrete and CNC: how to mould
  – Seminar: The architect as material designer

Workshop-seminar 4 (17.-19.01.2011)
  – Workshop: Generative Logics: how to grow
  – Seminar: Generative Design Thinking

Workshop-seminar 5 (22.-24.08.2011)
  – Workshop: Textile logic: how to brace
  – Seminar: Complex Membranes and the Variegated Materials
The Digital Crafting network activities were consolidated in two large scale international symposia inviting researchers and practitioners from the fields of architecture, engineering, fabrication and design to discuss their enquiries into digital design practice. Inviting practitioners from leading architectural and engineering firms as well as researchers from parallel research institute focussing on computation, design and fabrication, we initiated critical debates on the role of the new expanded digital chain and the ways that this impacts on design practices. The symposia had a strong international focus, aiming to expand the perspective and bridge different research cultures and critically reflect on the scope of the research project and its practical as well as theoretical consequences.
WORKSHOP 1
08.-10.02.2010 · WORKSHOP AND SEMINAR

PARAMETRIC DESIGN: ENCODED BEHAVIOUR

CITA
ROYAL ACADEMY OF FINE ARTS, SCHOOL OF ARCHITECTURE, DESIGN AND CONSERVATION

WORKSHOP GUEST: PAUL NICHOLAS
WORKSHOP AIMS

Parametric design introduces a new depth into architectural design. Where architectural design traditionally takes place within the absolute extensions of a projective geometry, parametric design tools enable the construction of variable geometries. Here, design is fundamentally understood as relational and geometry the potential to change as design information is altered. This shift in design logic allows for the development of performative models, where the design can be continually tested, evaluated and changed within a structure of constraints, variables and parameters.

The ‘Parametric Design and Encoded Behaviour’ workshop explored the encoding of material behaviour to inform parametric design models. During the workshop we examined how the properties of material flexibility – then bending of wood and steel elements and tension of fabric membranes – could be integrated into the design of a composite component system.

The workshop asks:
- How can variable material performances be incorporated into architectural design?
- What are the design systems needed to include complex behaviour of composite elements and structures in the early design phases?
- What are the consequences for the way we develop spatial, structural and material solutions?

Workshop Guest: Paul Nicholas

Paul Nicholas holds a PhD in Architecture from RMIT University, Melbourne Australia, and joined the Centre for Information Technology and Architecture (CITA) as an Adjunct Professor in 2011. Paul’s particular interest is in computational approaches that support interdependent design and thinking by establishing new and different links between architecture and other fields. Having previously worked at Arup Melbourne from 2005 and Edaw London from 2009, his current research explores the idea that composites, or designed materials, necessitate new relationships between material behaviour and digital representation. Paul co-founded the design practice Mesne in 2005, and has exhibited in recent Beijing and Venice Biennales.
The first Digital Crafting workshop ‘Parametric Design and Encoded Behaviour’ was held at the Royal Academy of Fine Arts, School of Architecture in Copenhagen February 8-10 2010. Organised by Martin Tamke of CITa with guest workshop leader Paul Nicholas of Mesne design studio, the three-day workshop brought together seventeen designers from the fields of architecture, engineering, design and computation to explore new ways of understanding material performance. In conventional design practice, thinking about materiality usually commences in the middle and end of the design process. During the workshop, we explored material quality and performance as design drivers, engaged at the initial stages of the design and leading to new spatial and structural solutions.

The aim of the workshop was to create a research environment to observe, measure, input and relate material behaviour to a parametric design model. This was seen as a way to begin to understand and control material performance in a component based system. The workshop included short group design exercises, material experiments using timber, steel rod and textiles. Throughout the workshop there were group discussions, presentations and reflections on the design and production process. On the final day, the group worked together to assemble a full-scale prototype.

The workshop focused on a simple parameter, the bending of a flexible material. Using wood, workshop participants were able to simulate the behaviour of the wood components and encode this as information in a digital model. The workshop used Grasshopper as a visual form of coding. The relationship between the material and the digital was approached at full scale through 1:1 material studies. This allowed participants to encode the material performance data gathered through experimentation into the digital model. During this process, the group debated issues of accuracy. When measuring by hand, there is a degree of abstraction and error, which stands in contrast to the precision of digital calculation. Participants discussed if methods for parametrically encoding material performance should be focused on accuracy or on the relationships between elements.
Using this technique of empirically testing the wood elements, the workshop proposed new ways of describing the complex behaviour of the material. The bending of the wood elements follows a mathematically defined curve and there are ways of abstracting and calculating the form relating the constant length of the perspectives. How the material compresses. However, using this empirical method, the material performance is tested and inputted into the digital model without the designers needing to explicitly define its mathematical formula. Using this strategy, parametric thinking offers designers the opportunity to link between material behaviour and computation.

The group discussion explored how this new, parametric-material way of thinking could change the way architecture is designed and built. Proposing an alternative to traditional engineering design, which focuses on stabilising material performance to ensure structural integrity and uniform behaviour, this new digital design practice suggests new materially informed perspectives.
Interview with Workshop Guest

PAUL NICHOLAS

How do you use parametric design in your design studio Mesne?

Within Mesne we use parametric design to represent and engage complex systems and organisations through simple sets of local rules, and to simultaneously think about concrete architectural qualities and abstract organisational structures.

This begins with using the tools to capture a design idea and to develop the systems, structures and procedures that will bring the design into being. Parametric design allows us to rigorously explore the possibilities of these structures and designs that are possible within the given constraints. This typically involves linking the parametric model to performance analysis via feedback loops.

How do these ideas relate to the Digital Crafting workshop goals and outcomes?

One of the workshop’s underlying ideas is recognising that material behaviour impacts designs and the design process. Usually material behaviour is viewed as something to be ‘overcome’ and designers try to ‘design out’ that relationship by minimising behavioural change. In the workshop, we aimed to develop an alternative approach in which material properties became engaged as active and constructive influences on geometry. In the workshop, we were able to explore the relationship between geometric and material properties in design. Parametric design can engage many different levels of design decisions from space planning to structural design to the actual fabrication of individual elements. By linking parametric tools to the low scale of material behaviour, we were trying to find new ways of understanding the consequences of these inter-scalar relationships in architectural design practice.

In the workshop, these ideas became a starting point for the practical exercise where we asked ‘How do you draw the bend of a stick?’

At its core, a parametric model is a geometric system defined through associations and relationships, and that operates within given constraints and limitations. In the practical exercise with the sticks, we were all able to see that paramet-
ric design is actually quite capable of capturing this kind of behaviour for use in design. The intention of the ‘stick exercise’ was to understand how material behaviour might be thought of in these terms, in this case as a relationship between deformation and a particular condition of loading and restraint, and to then connect our physical exploration of behavioural change with the digital definition of a design space.

As a group we had many discussions about the changing role of the designer in both design and fabrication. In your work with Mesne, you are aiming to create a different relationship in design and fabrication so that key fabrication issues which impact quality, speed and cost can be addressed early on. In the case of the Melbourne ‘Travellers’ sculptures, how did you consider assembly and issues of fabrication?

In this project, because of the tight timeframe and complex geometries, the entire digital design process was structured around issues of fabrication. This approach centralised the fabricator, who is normally a peripheral figure, and involved him in the development of the digital processes, which included rapid prototyping, scripting and automated production of machine code driving the digital fabrication. The most important result of this involvement was that the fabricator could understand the design and have confidence in the resulting machine code.

With this project, how did you use the shared digital model and what were the opportunities and challenges?

Had the same project moved through a traditional representation and procurement cycle then arguably the project would not have met the constraints of time or budget. We pre-ordered all the steel based on digital information, and then welded around 5000 uniquely bent sections from machine code without producing shop drawings. The project demonstrated the opportunities that shared digital models can provide to reconfigure a design and production process around non-traditional information flows, and to add real value.

There seems to be a key concept that communication is extremely important in parametric design. How can designers and others in the design and fabrication process share digital information?

One thing that is interesting about parametric tools is that they are capable of embedding at least two levels of useful information, at the heuristic or ‘rule of thumb’ level and also at a more detailed level. The heuristic level is not as accurate, but can be a very powerful way to communicate an idea or design intent, which is the most important but difficult to capture kind of information within the early design phase.

What would be an example with Mesne, where you share information in this way?

In the Bendigo Canopy project, a structural sensibility was back-propagated into the geometry creation process through the encoding of structural rules of thumb, which captured and synthesised engineering and architectural intents in a form. Using RhinoScript for a structural optimisation routine, this allowed us to iteratively explore design alternatives and to keep pushing the design intent, but also to understand the engineering drivers and their impact upon the geometry.
Parametric Design and Encoded Behaviour Seminar
10 February 2010

Presenters
Paul Nicolas, ‘Performance Driven Design as a Means for Design and Fabrication’
Architect, mesne.net,

Mette Ramsgaard Thomsen, ‘Performance Driven Design as a Method for Material Specification’
Professor, CITA, Royal Academy of Fine Arts School of Architecture,

Hauke Jungjohann, ‘Performance Driven Design for the Generation of Structure and Façade’
Engineer and Architect, Knippers Helbig Consulting Engineers,

Parametric design tools allow the integration of material information (material specification, structural performance, fabrication data) within the design process. If architectural design is traditionally understood as a process refinement, parametric tools allow for feedback between the defined design stages thereby suggesting new informed workflows. The versatility of these tools, and the ability to work with dynamic rather than static data sets, proposes a new understanding of design practice.

The seminar asks:
- How are these design parameters accessed and declared?
- How do these tools challenge disciplinary boundaries?
- What happens when multiple parameters of material, environmental, spatial and structural data are integrated?
- How can parametric design tools challenge the material cultures of design process and production?
Your presentation at Seminar 1 was titled ‘Performance-driven Design for the Generation of Structure and Facade’, can you explain what you mean by ‘performance driven design’?

In a technical sense, the performance of a building is its capability to prevent heat loss, to absorb sound, to have a sound structure or perform in any other physical manner. It should also be the creation of aesthetically desired views and in a wider sense, the capability of providing an appealing and liveable environment. By measuring various performance metrics and feeding the results into an automated design process, we gain the ability to build up an iterative process, which can result in identifying the best-performing design solution given a specific design context. A ‘performance-driven design’ is therefore to some extent automated, but the designer always makes the final decisions or if necessary adjusts the workflow.

Has your use of parametric design tools changed over the years? Is there a way you see things progressing, towards a new kind of workflow?

At Knippers Helbig, our main focus is on the structural and façade performance of a building. We are interested in designing optimal solutions and therefore use complex software and automated design processes. The building and software industry provides limited optimisation tools where the output could be linked to the input. Ten years ago, we started to use custom computer programs to link different software solutions together to build up our own parametric workflow. We are continuously updating these. Although some current software programs provide parametric modelling, only a few also integrate engineering performance, and then only to a limited extent.

Since this way of working is highly software dependent, I expect one of the big software companies to eventually release a complete software package that is suitable for daily use.

The seminar referred to ‘the materially aware model’ as a means for design, material specification and fabrication. How have these ideas featured in your work? In your seminar presentation, you showed the Shenzhen Airport
project that you worked on for Massimiliano Fuksas’s office, which has a 1.3km long concourse and a double skin façade that used parametric panelisation tools to control aspects of performance. How are these practices connected?

At Knippers Helbig, we received our engineering education in the environment of Stuttgart’s famous engineers like Fritz Leonhard and Frei Otto. We use form-finding algorithms on a daily basis where we optimise the form so that materials and resources are minimised.

We use this approach for most of our grid shells and at present are planning a project in China where we precisely optimise the form so that profile heights are minimised and the lightness of the structure is maximised. In the Shenzhen airport, we used a full parametric model and certain performance criteria like energy gain and views as input parameters to optimise the geometry.

How have ideas from the Digital Crafting network been relevant to your ideas of thinking about materials at different scales - are you working on any projects that touch on these themes?

The Digital Crafting network is important because its multi-disciplinary approach provides a platform to communicate practices and knowledge allowing designers to rethink their own way of approaching a problem. Our office works in a similar way on most projects combining design, analysis and research.
WORKSHOP 2
29.- 31.03.2010 - WORKSHOP AND SEMINAR

WOOD CONSTRUCTION: HOW TO JOIN

CITA
ROYAL ACADEMY OF FINE ARTS, SCHOOL OF ARCHITECTURE, DESIGN AND CONSERVATION

WORKSHOP GUEST: CHRISTOPH SCHINDLER
This workshop investigated the consequences of digital fabrication on wood constructions. Focusing on the logic of the joint, the starting point was understanding and analysing the typical production processes in timber construction component. Customised, self-registering joints, such as the dovetail joint, are fundamental to the traditional wood building industry. They allow the rapid assembly of complex geometries. Industrialisation and the use of CNC fabrication has perfected this approach in various snap fit solutions.

The workshop asked how the introduction of CNC tooling can lead to new solutions for timber construction. Through analysing the history of the tools and joinery traditions for timber construction, the workshop identified that CNC tools can be understood as extensions of traditional tool sets. These toolsets have established craft traditions associated with them. However, linking tooling to coding offers a new scale of engagement as designers can now work with higher degrees of complexity.

The workshop asks:
- How traditional craft techniques and increased complexity can lead to innovation.
- What happens when ‘snap-fit’ ideas meets architecture?

Workshop guest: Christoph Schindler, schindlersalmerón

schindlersalmerón dedicate their work to the development of parametric objects at the interface of architecture and product design. Well-known examples of their approach are the parametric coat rack ‘Kleiderleiste’- one of very few customisable products in the market—and the awarded wood construction principle ‘Zipshape’. The firm is interested in both digital fabrication and traditional workmanship. Christoph Schindler’s experience ranges from intelligent design objects to developing realisation strategies for large complex building projects in his former position at ETH Zurich and design-toproduction. In his writing, he seeks to embed contemporary development into a broad historical understanding of production technology.
The second Digital Crafting workshop ‘Wood Construction: How To Join’ was held on March 29 and 30 2010 at Royal Academy of Fine Arts School of Architecture in Copenhagen. Organised by Martin Tamke of CITa with guest workshop leader Christoph Schindler of schindlersalmeron, the participants worked to explore the parametric possibilities of Schindler’s ‘ZipShape’ method. ZipShape is a method of production that allows the fabrication of single curved panels from any plain material without molds by creating two individually slotted panels that interlock like a zipper when bent to the predefined curvature.

Working in small groups, the two-day workshop allowed participants to create formal and geometric experiments using digital models, which were materialised using digital fabrication as part of the design process. This allowed the participants to create prototypes and learn from physical models. The workshop began with an introduction to the ZipShape principles and participants experimented with the parametric manipulation of given design scripts. Working in small groups, the participants created propositions for new ZipShape investigations relating to material performance.

Group 1 challenged the idea that the method could only be used for rectangular sheets and single profiles. They began by projecting a series of freeform shapes onto the rectangular zip-sheets and trimming them, resulting in generating more loosely defined and open-ended surfaces. They worked back and forth between digital and physical models, developing ideas in the digital model and then outputting these to physical foam models that they then tested and manipulated. They experimented with different designs for the two zip-sheets and found different forms for the ‘teeth’.

They discovered that the foam material did not work well with steep curvatures where small areas in between the ‘teeth’ would easily break. Testing the tolerances and properties of the material, they were able to create studies that developed new applications of the Zip concept.

Group 2 investigated complexity through standardisation in a series of prototypes that experi-
mented with alternating the thickness of the zip structure. They made a ‘zip worm’ prototype and tested new ways of covering the sides of the Zip. They found that the foam material did not work well in tension as it quickly broke. Working back and forth between digital models and quick foam prototypes, the group also experimented with ways of creating Zip structures in which the number of ‘teeth’ could vary with the bend of material.

Group 3 were interested in the space defining possibilities of the method and studied interlocking spaces. They asked ‘could a design be developed that can grow as more pieces are joined in a tiling system?’ The group explored different curvatures and tried to introduce splits in the components that could curve in different directions.

By creatively analysing and testing the Zip-Shape method, workshop participants were able to investigate the design possibilities of this adaptive form-giving system.
In your lecture, you said that architecture is becoming more about showcasing the process, the ‘how’ of a building and maybe less about the ‘why’ – How does this relate to parametrics?

This is one of the big questions raised in our discipline today. Most of us grew up with an education that understood architecture as part of the arts and thus history of architecture as a part of art history or at least cultural history, applying terms such as ‘styles’ to describe and structure its development. Today, nobody doubts the central role that information technology has taken, or is about to take, in the building sector. 3D-modelling tools, parametric models, research on self organisation and computer-aided machine tooling are not only omnipresent, but appear to have become the self-sufficient focus of the discourse.

It is difficult to relate those technologies and their formal output to art history as we know it since the 19th century. Therefore I wonder whether it could be the history of technology itself which might help us to describe and contextualise the contemporary developments in architecture.

Does this relate to the discussions we were having relating to mass customisation and how it could relate to parametric design?

The term ‘mass customisation’ was coined in the context of customer integration as a concept offering individual products to individual people, such as tailor-made suits. Thanks to computer-aided manufacturing systems, these products could be offered for the price of mass production. For some reason, mass customisation as a concept of customer relationship marketing has not taken off so far. However, the term was discovered by architects and started a successful career in architectural discourse. What lost significance in the architectural context is the individual customer as a good reason for individual production—and thus somehow the socio-cultural backbone of mass customisation.

ZipShape does not necessarily relate to the material qualities of wood, did you try anything else and why have you chosen to work with wood? What challenges and opportunities have you found working with wood?
The toothed section of a ZipShape panel consists of two different areas—the ‘teeth’ and the thin sheet that connects them. While the teeth are defining the geometry, the thin sheets connecting them take most of the tensile forces, just like in a trussed beam. The teeth do not relate to the specific material qualities of wood, whereas the sheets have to resist to tension and be bendable at the same time. This makes it a perfect match for wood’s fibre structure and its anisotropic behaviour. For the ‘ZipRocker’ rocking chair, we even used different wood materials for these two areas: low-priced pine boards for the core with the teeth and high quality plywood layers for the sheets.

In the workshop, we used foam, rather than wood, so instead of learning about wood as a material, we looked at parametric design and ZipShape relating to form and geometry. From your perspective what worked and what could have been improved in the workshop?

As the geometry definition relies on the teeth’s shape, and the teeth are not making use of wood properties, we started our experiments with Styrofoam, which we could machine quite quickly on site. We were intending to use wood in a second phase to investigate structure, bending behaviour and the time-consuming gluing process with a vacuum bag—but we got captured by the experiments with ZipShape’s geometry and never made it to the second phase within the two days of the workshop. However, I had never done ZipShape experiments with foam and was thrilled with the manufacturing speed and especially with the ease of bending without a vacuum bag.

Building on the experience from Copenhagen, we are planning right now an exhibition design in Switzerland using foam.

You have said ZipShape is at the interface between product design and architecture. Could you describe the upcoming Shanghai Expo project that uses ZipShape?

The DuC-Pavilion at the Expo 2010 is a part of a three-year program for German-Chinese cooperation. The pavilion is actually a bamboo construction. ZipShape was used for some curved, ribbon-like elements in its interior design that could not have been realized with conventional methods. The ZipShape components composed eight ‘ribbons’ with a total length of almost 40 meters. They were manufactured from MDF with beech flanks and linoleum surfaces. The ribbons served as a platform for an interactive simulation of sustainable urban planning. It is the first public application of Zipshape and therefore an important test case. The project was realised in collaboration with the chair of Peter Russell at RWTH Aachen University.
Workshop 2 Seminar Topic

The Ideal of the Tectonic: The Tectonics of the Joint

31 March 2010

Presenters

Michael Hensel, Professor of Architecture, Head of the Research Centre for Architecture and Tectonics, The Oslo School of Architecture and Design

Sigurdur Omasson, Associate Professor, Technical University of Denmark, Copenhagen

Silvan Oesterle, Swiss Federal Institute of Technology, Zurich
Professorship Gramazio & Kohler, Architecture and Digital Fabrication, ETH Zurich

Sebastian Gmelin, PhD Researcher, Aarhus School of Architecture, Denmark

The seminar invited leading researchers to discuss new perspectives in timber construction. Bringing together presenters from the fields of engineering and architecture, the seminar discussed how material modelling in timber construction can inform design. The seminar questioned the many scales of production, design and fabrication that impact on our understanding of material design. Timber is a natural material and as such heterogeneous in structure. However, industrialisation has sought to regulate the production of timber elements so as to ensure standardised material for a systematised production industry.

The seminar asked
- What tools have been constructed to guarantee material consistency?
- How are the inherent interdependencies between how to grow, design and manufacture with timber managed?
In your lecture you introduced the m-many project, a full-scale digitally fabricated construction you worked on during your final year of study at ETH Zurich. Can you describe the project and the design intentions?

It is called ‘m-any’ because it was designed to be able to materialise in many different shapes and at any location. It was the final thesis project of the Master of advanced studies in Architecture CAAD course 2004 / 05 at the ETHZ at the chair of CAAD (Prof. Ludger Hovestadt). All seven students of the course were working on it: Tobias Bonwetsch, Sebastian Gmelin, Ber- git Hillner, Bart Mermans, Jan Przerwa, Arno Schlueeter, Rafael Schmidt.

The main idea of m-any was to develop a proof of concept for a ‘complete digital chain’. This term was used a lot at the Chair where we studied, it means that the heavy design data of complex geometries was developed through a digital process from the first idea to detailed drawings to production code until the final CNC process without having to manually redraw everything. In order to do this, we developed special digital tools and scripts. We developed a form-finding software using cell-packing algorithms. This allowed it to be a flexible system. Each construction part is represented by a cell, which in turn is represented by a sphere.

The cells try to create a compact arrangement – they attract each other without creating overlaps. Also, they grow until they reach the construction part size limit – then the cells splits and a new construction part or cell is born. The system grows until it reaches the desired overall size of the structure. The cells react on external conditions that were translated into forces influencing the system. The cell arrangement is used to generate a voronoi wireframe and data-set. This form finding tool was scripted as a stand-alone application in Java. The data was exported and a script was written to generate a detailed 3d model of the construction with a series of main parameters like material thickness, milling tool to be used, etc.

The script also unfolded the geometry and created labels numbering the parts. These drawings were used to fabricate the parts on
a 3 axis CNC mill and a laser cutter. We tried to use scripts as much as possible to generate the shape. Also we wanted to automate the full process from form-finding to production. But we did this in 2005 and it is now is definitely not new anymore. Parametric tools like Grasshopper basically offer a lot of the functionality, which at the time, we had to script ourselves.

Can you describe the process of taking the design from digital to physical?

The whole design was developed with a specific physical construction and the particular tools, a mill and laser cutter, in mind. We automated the process very well. All production drawings were produced automatically and this data was taken to the mill and the laser cutter. We were not able to produce our own ‘G-Code’, which is the data driving a CNC machine. With a 3-axis mill, the G-Code is basically a series of 3d coordinates to move the tool. In a perfect ‘digital chain’ the scripts would create this code directly. In our case, we had a special program reading our drawings and creating the code for us. We had to take the data through a milling software to create the milling paths. Here we encountered a typical problem: it was very time-consuming to erect the structure, especially to find the right pieces. At the time, we could not automate this. Gramazio and Kohler are currently trying to find answers to this problem, using robots to assemble their installations.

How do you see the m-any project relating to the Workshop ideas?

During the workshop, we discussed methods of joining and assembly and this is a relevant topic when it comes to complex geometries as both the joints and the components need to react to all sorts of different arrangements (number of connecting pieces, angles, sizes, etc.) The digital needs to reflect the physical and it is crucial to find good joinery solutions – with m-any we chose a clicking system to avoid thousands of screws.

Usually on a project, more people become involved for assembly, to build the design on site. Ideally the complexity is solved before this stage. With the m-any project we created interlocking
joints with separate connector pieces to click the elements together. It was quite a long process to develop a joint that could create enough tension for the locking. These connectors were laser-cut rather than milled due to lower tolerances. The final, built, design consisted of over 1000 different pieces. They were all numbered using a coding system we developed for the project – it had to be milled using a thick milling tool to run at enough speed to meet the deadline. Both in the Digital Crafting workshop and with m-any, it became clear that assembly time is a major constraint for a design.
WORKSHOP 3
18.- 19.08.2010 - WORKSHOP AND SEMINAR

CNC & CONCRETE: HOW TO MOULD

DANISH TECHNOLOGICAL INSTITUTE, COPENHAGEN

WORKSHOP GUESTS: ASBJORN SONDERGAARD, JOHANNES RAUFF GREISEN
Digital fabrication is changing the way architecture is designed and built, leading to new structural opportunities. Direct interfacing between design and production enables a higher degree of material detail, which has the possibility to fundamentally reform the material practices of architecture.

When considering the ‘wet’ processes of casting the interfacing of digital design with CNC milling has allowed a new generation of highly complex and individualised moulds to be produced directly from the 3D modelling environment. This facilitates the development of bespoke formwork at highly reduced costs and low material intensity. In parallel the development of rapid-manufacturing technologies suggests a new design practice where materials are directly specified and detailed as part of the design process.

In this workshop we investigated guiding research questions for understanding a new generation of digitally designed materials. We explored the making of bespoke formworks, the casting of structural elements and questioned how the increased level of detail and complexity can lead to new structural forms. We looked at how a new generation of morphogenetic tools enable structural optimisation and discussed how this material logic can be encoded into digital models.

The workshop asked:
- How can new programmed design tools present alternative ways of thinking about the relationship between the mould and the form?
- What new structural opportunities emerge from investigating these relationships?
Workshop guests:

**Asbjørn Søndergaard, Aarhus School of Architecture**

Asbjørn Søndergaard studied at Aarhus School of Architecture, and is the founder of Design\Compute, a design firm framing architectural design experimentation in the field of structural optimisation and computational tools. His research focuses on morphogenetic processes and the development of novel structural logics in relation to digital fabrication techniques. In collaboration with civil engineer Per Dombernowsky, he has been responsible for a number of structural optimisation case studies within the collaborate research project ‘Unikabeton’.

**Johannes Rauff Greisen, Danish Technological Institute Concrete Centre and Royal Academy of Fine Arts, School of Architecture, Centre for Industrialised Architecture**

Johannes Rauff Greisen, Architect MAA, is consultant at the Danish Technological Institute Concrete Centre, working on his Industrial PhD project at the Royal Academy of Fine Arts, School of Architecture, Centre for Industrialised Architecture. The objectives of his research are exploring the architectonic potentials of utilising industrial robots in concrete building. He addresses the architectural design process as a result of material-driven, vision-driven and fabrication-driven processes.

*The Digital Crafting Network thanks The Danish Technological Institute for hosting the workshop. Thank you to Thomas Juul Andersen and Johannes Rauff Greisen*
The third Digital Crafting workshop ‘CNC and Concrete: How to Mould’ was held at the Danish Institute for Technology in Copenhagen August 18-19 2010. The workshop was organised by Mette Ramsgaard Thomsen of CITA, Claus Peder Pedersen of Aarhus School of Architecture and Thomas Juul Andersen from the Danish Technological Institute and invited guest workshop leaders Asbjørn Søndergaard from Aarhus School of Architecture and Johannes Rauff Greisen, from the Danish Technological Institute Concrete Centre and Royal Academy of Fine Arts, School of Architecture, Centre for Industrialised Architecture.

The two-day workshop allowed participants to explore CNC milling of bespoke moulds for concrete casting creating a full scale prototype. The workshop used topology optimisation as a digital technique for developing three individual panels that made up the prototype.

The first day was spent largely working in small groups, creating the digital design of the three panels. The pre-optimised, overall geometry of the design was given to the participants at the start of the workshop. These rectangular panels were taken into a topology optimisation software and here the load conditions were specified.

The resulting forms were adjusted for manufacturing requirements including minimum thickness of concrete and geometric constraints. The final panel design was then exported to the CNC milling software where the tool paths for informing the milling robot were created.

The next day, the moulds were cut. The groups developed three different strategies for milling the elements. By differentiating the milling time, three levels of coarseness and detail were created, from the very fine to the very rough. This differentiation was a practical decision as well as an experimental one. As the time in the workshop was limited, the groups varied the cutting time from eight to four and finally to two hours. These resulted very different aesthetic expressions.

After the milling, reinforcing bars were set into the moulds, the release agent added and the concrete poured and levelled. In the morning
of the third day, before the seminar, the concrete forms were carefully broken out of the milled moulds and cleaned off.

Discussions and presentations during the workshop questioned the role of morphogenetic tools in design and how these can allow for structural optimisation.
During the workshop, participants visited the topology optimised concrete structure produced during the Unikabeton research project by researchers Per Dombernowsky and Asbjørn Søndergaard. Fabricated using the large-scale industrial CNC-milling facility at Danish Institute of Technology, the structure represents the first realised topology optimised concrete structure. The structure is a full-scale prototype which informed the optimisation experiments undertaken at the Digital Crafting Workshop 3. The prototype reflects the morphogenetic principles of design and conceptualisation facilitated by the method of topology optimisation.

As workshop leader, what were your intentions with the workshop?

The idea was to offer a platform for a 1:1 experience with the morphogenesis of topology optimisation in relation to robotic fabrication. We wanted to facilitate a discussion of the implications of the field with regard to related theoretical discourses and technological aspects of production. In the workshop, we explored the cycle of optimisation, remodelling, full-scale milling and casting all within 3 days. I think the most successful part was delivered by the participants in their dedication to the workshop content and the discussion that arose from it.

In your introductory lecture, and in the Seminar presentations on the final day, we were discussing the aesthetics of topology optimisation. What parts of this discussion do you think are the most relevant for designers?

It is often the case that a type of formal language emerges as the result of intensive work with material experimentation and then this language is adopted by others that take interest in the appearance, but not in the process behind it. The language then becomes self-referential, but without its former meaning. This sometimes happens with so called ‘optimised’ structures. Actually, the first large-scale topology optimised structure to be realised – the Qatar Convention Hall by Mutsuro Sasaki – is a good example of this. The structure was originally conceived by a process of optimisation, but then simplified into an...
internal steel rod skeleton clad with non-load-bearing steel plates that imitates the original optimisation output. This means that the design lost most of it initial structural logic in the process of realisation, although it still formally appears ‘optimised’.

*How can we interpret the optimised results? Can something be really ‘optimised’?*

In the seminar we discussed two opposite positions on this. The first position is to say the most interesting results arises directly from computation, without the designers interfering or ‘polluting’ the optimisation results with their formal preferences.

The other position is that the most interesting results arise through the designers interpretation of the results, and that the computational process should only contribute to the appearance of the design. In my opinion, the first position does not take into account that the premise for any computational process is manmade. No matter how strictly mathematically the process may be, there will always be a modelling setup preceding it, in which several design threads can be pursed, tried and discussed. Also, the computational results need subsequent interpretation in preparing the form for production and manufacturing – and this is also an area of aesthetic evaluation. The optimisation result is therefore derived by both structural and aesthetic considerations. To misunderstand this is to repeat the modernist attempt to avoid the difficult but necessary question of aesthetics by claiming a false objectivity to the process. I think the question is rather: how do we affect the process of optimisation prior to its execution? And how do we choose to interpret the optimisation results formally? I believe many answers can be developed to these questions, varying on both cultural and technological conditions. The optimisation process may actually result in unexpected design discourses that could influence spatial concepts.
Workshop 3 Seminar Topic
‘The Architect as Material Designer’
August 20, 2010

Presenters

Neil Leach, ‘Machinic Processes’
Professor of Architecture, University of Southern California

Ole Sigmund, ‘Topology Optimization’
Professor of Mechanical Engineering, Technical University of Denmark

Marco Poletto, ‘Systemic Designs’
Co-founder of ecoLogicStudio and Unit Master at Architectural Association, London

Tobias Bonwetsch, ‘Tailoring Manufacturing Processes’
Researcher, Institute for Technology in Architecture, Faculty of Architecture, Swiss Federal Institute of Technology, Zurich

Digital fabrication allows an ever more detailed material address, enabling the architect to take part in the design of materials. Using digital tools, materials can be highly specified and individualised. By inviting speakers from research environments working with optimised casting technologies and digital printing the seminar sought to create new links between these ‘wet’ processes of manufacture. Questioning the different scales of application, the seminar reflected upon the new opportunities for thinking structure both at building scale and at material scale.

The seminar asked:
- What are the underlying logics that can inform digitally designed materials?
- How can the ability to implement advanced coding such as genetic algorithms in our designs have impact on our material practices?
- How can new technologies for casting and printing suggest an expanded understanding of composite structures?
Unikabeton
Suspension arm optimized with software “TOSCA Structure” by FE-DESIGN GmbH
Ole Sigmund is a Professor at the Department of Mechanical Engineering, Section for Solid Mechanics, Technical University of Denmark. He researches the design of extreme materials, smart materials, compliant mechanisms and fluid systems and has contributed substantially to the field of topology optimisation and co-authored the influential publication ‘Topology Optimisation: Theory, Methods and Applications’. His lecture was about the applications of topology optimisation, and about how materials can be designed to be better performing and solve complex design problems. Following the lecture the group discussed optimisation in relation to material and material design.

Could you elaborate on the design potentials of designing for optimisation and the challenge of scale - for example nano-scale to building scale in material design - as it applies to your research?

Of course there is a scaling issue since currently our nano-material based structures are very small. However, with improved manufacturing methods this will come soon. For example, one of our current research projects is concerned with surface structuring of plastic parts on bottles with the goal of saving costly painting. We use mass-manufacturable, nano-imprint technology to stamp nano-structures into plastic surfaces, in turn changing their colours and making them hydrophobic.

This relates to the toy example you described in your lecture – the Harry Potter figurine by Lego? You mentioned that the most expensive part of the process is not the creation of the ten parts which are assembled to create this figure but actually the way that the glasses and face need to be painted on the figure’s head, separate from the injection moulding process? In your lecture you proposed a new way of creating this, using actual material deformation rather than pigment.

Yes, we are taking inspiration from butterflies. If you take a microscope and look at the surface of their wings they have nano-structured surfaces that actually create the colours that we see. The butterflies actually designed their surfaces in
order to absorb light at different frequencies. In this project our job is to make the nano-structuring of the Lego part so that we don’t have to use paint. Instead it just becomes an absorbing surface that makes it look like we painted it. With regard to scale, of course from smaller plastic parts to building parts there is still quite a step. However, I am convinced that this gap will be bridged within the coming decade.

There was some discussion about manufacturing constraints and how this must be built into topology optimisation design, how do you design with these limitations?

Different manufacturing methods have different limitations. For example in concrete casting it is not directly possible to introduce internal voids. In many cases void regions inside the structure would be structurally beneficial and hence the results of the optimisation would contain holes. To align the topology optimisation process with the material practices involved, we therefore introduce constraints that prevent the creation of internal holes in the structure.
This led to a discussion about the aesthetics of optimisation. How can something ‘look’ optimised or not? You said you could tell if a structure had been optimised or not when you claimed: ‘Whenever I see a structure with circular holes I know it has not been optimised’. What do you think about the relationship between aesthetics and optimisation?

I certainly think that an optimised structure is beautiful. However, due to my training I see many flaws in ‘optimised structures’ that ordinary people would not see. Hence, a structure with many circular holes may look light and efficient for many people, however, in my eyes I see stress concentrations and waste of material. Also, if I see a curved bar that is supposed to support longitudinal forces, I know that the structure is not optimal. Unfortunately one of the workshop structures has such features –this I partly attribute to bad post-processing steps in the used software.

A good example of this faulty optimisation is the CCTV tower in China designed by OMA Architects and Cecil Balmond at ARUP engineers. The outer structure is claimed to distribute the forces in an optimal way, however, to me it is clear that it is by no means optimal and that a much better solution - and possibly even better looking - could have been obtained using topology optimisation. Unfortunately I never found time to test it but I will try to find some students who can perform the optimisation study.

What did you think were the most interesting aspects from this Digital Crafting Seminar?

It was interesting to see the broad range of speaker topics –from my very basic engineering structures that fulfil well-defined optimisation goal to the very artificial and complex structures produced by various digital processes. For me, structural beauty is a natural bi-product of the structural optimisation process. I hope that this message will be remembered by the participants. The artificial digital processes are also very interesting but I think they should be hooked up with some measures of efficiency to become well accepted in a world that becomes increasingly aware of limited natural resources.
In the workshop and seminar, we talked about optimisation in relation to material design, how does optimisation relate to your work?

Optimisation in architecture is somewhat a fuzzy concept, which is often applied to functional, engineering aspects, where the optimisation criteria can be more easily defined and made explicit. But architecture is also about spatial qualities, aesthetics, usability over time and so forth, properties that can hardly be put into fitness functions. In the robotic processes we develop at ETH, we inform building elements through the selective placement of material and here all these factors play together. This results in a lot of redundancies in the final material-system or element, but at the same time gives them a unique appearance and sensuality. I think design has to be considered as a whole, in the same way that architecture is not just about engineering it is also not just about material.

In our work at ETH and with the students we look at the aggregation of material. Our work is always about the combination between material, the definition or creation of a certain fabrication process (material manipulation) and computation that drives and controls the process. The student work examples I showed in the presentation take a given material and rethink its use when applying the potential of a computer controlled, self-defined fabrication process. This also affects performance issues.

Having computational control these different material processes shifts architectural design from the design of geometry and surfaces towards the design of the fabrication and construction processes.

We talked a lot about the aesthetics of optimisation – how can and should something ‘look’ optimised? What is the role of the designer in optimisation?

Again, optimisation can be applied to many different and very diverse requirements in architecture. Can and should something look optimised? Probably not. In the simple material and construction elements we look at, the interplay of the individual parts create...
a complex system, beyond the functionality of its single members. They are not specialised or optimised for a specific function, instead their appearance is a combination of different functions as well as aesthetic considerations.

In your opinion, what makes this Digital Crafting seminar relevant in the context of contemporary practice?

I believe ‘digital craft’ is highly relevant for architectural practice - at least if you believe that architecture establishes itself in its physical form. The tools are here today, but we are yet only scratching the surface. The architect is now in the position to directly intervene with the process of making. The design can be driven by the definition of a physical fabrication process rather than by an overall geometry. This requires developing an understanding of architectural and structural potentials of these new technologies.
Recent years have seen the establishment of a shared digital platform creating new interfaces between the disciplines of architecture, engineering and construction. The introduction of computational logics has led to the making of advanced digital toolsets and we are now observing the formation of new inter-disciplinary workflows.

The first Digital Crafting symposium asked how the progressive integration of design, analysis and making challenges the knowledge spaces of architecture, engineering and craft. Examining the emerging collaborative practices, it sought to frame and present the new potentials for an integrated building practice.

The seminar invited nine speakers from professional practice and academic research and was organised in three sessions each with a driving research question:

Session 1, ‘Computation and Fabrication – How to fabricate?’ asked how digital fabrication is changing today’s building practice. To make use of this technological platform it is important that architects and designers find ways of interfacing between design and fabrication. This session discussed computational design techniques and the new forms of collaboration that rise from this shift in material practice.

Session 2, ‘Computation and Simulation – How to Analyse?’ discussed how digital tools challenge the traditional hierarchies in the building design process. Traditionally design and analysis are seen as subsequent steps in the design process. As new computational tools merge design and simulation we enter a new practice in which analysis can become integrated into the early design phase. This session discussed different simulation approaches and the consequences of this new practice for the profession.
Finally session 3, ‘Computation and Design—How to design?’ questioning the ways in which these new shared digital platforms can lead to new spatial opportunities. During the last 10 years the profession has developed a new algorithmic modelling practice that introduces coding as a design tool. This session discussed recent developments in computational design that challenge the core architectural concerns of spatial programme and material construction.
Michael Meredith, MOS

‘Physics vs Geometry’

Michael Meredith is Assistant Professor of Architecture at the Harvard University Graduate School of Design. His professional practice engages interdisciplinary discourses, ranging from art to technology, producing a spectrum of design work which includes furniture, products, sound, speculative architecture projects and residences in New York, Ontario, Texas, and California. Recently he was a finalist for the design of the Pentagon 9-11 memorial and the PS1/MoMA Young Architects competition. In his talk, Meredith presented an introduction to parametric techniques, discussing a shift he believes is taking place in architectural discourse. He says ‘the future is definitely parametric’, however his talk argues that there is an inability in contemporary state of digital techniques to address complex cultural and socio-political questions. Taking examples from his own work and education, he discussed what he observes as an almost schizophrenic divide between his approaches to projects for exhibitions and building design.

Fabian Scheurer, Design2Production

‘Digital Tools and Non Standard Architecture’

Fabian Scheurer is an architect and computer scientist who co-founded Zurich and Stuttgart based studio DesigntoProduction in 2005. DesigntoProduction implements digital process chains based on parametric CAD-models and offers consulting services for parametric planning, detailing, optimisation, and digital manufacturing. The office is known for their collaboration with UN Studio on the Mercedes Benz Museum in 2006 and their recent work with Shigeru Ban Associates for the Centre Pompidou Metz.

In his lecture Scheurer talked about how design and fabrication must be linked. Showcasing the same example as Antemann, the Kilden Performing Arts Centre by ALA Architects, he discussed the rationalisation process that he had been involved in to make the geometry of the proposal buildable. The design had a façade composed of oak, plywood, steel tubes and steel girders, giving the impression of a ‘waved wall’ facade wrapped in oak. Scheurer discussed the
ways in which the geometry had to be redrawn as a ruled surface as to be able to define the individual timber members as well as the underlying steel structure. Presenting the full process from design, through structural simulation and ending with the 5 axis timber CNC milling of the individual cladding boards and their site assembly, he demonstrated the achievements possible in non-standard construction.

**Max Maxwell, Supermanoeuvre**

*‘Computation and Design’*

Iain (Max) Maxwell is an Australian born registered Architect, design researcher and educator currently based in London. He holds a Masters in Architecture and Urbanism from the AA School London and is currently a tutor with the AA School’s Diploma Unit 16, London Metropolitan University’s Masters of Architecture and Digital Design Systems, and is an external advisor to the University of Canberra’s cross-disciplinary Masters of Digital Design. In 2006 he co-founded Supermanoeuvre, an award-winning design practice that has exhibited extensively in the USA, Asia, South America, Europe and Australia. In 2007 he was awarded the (Royal) Australian Institute of Architects Young Architect Prize.

In his lecture, he argued that in discussing craft, one must discuss process since the object and the way something is made are inextricably linked. Methodologies, materials, techniques and the narrative of design must be taken into account. Illustrating his talk with examples of Supermanoeuvre projects, he questioned how digital practice can lead to new formal possibilities for architecture.

**Martin Antemann, Bluhmer Lehmann Timber Construction**

*‘Fabricated Design in Timber’*

Martin Antemann is COO and member of the extended board at Blumer Lehmann Timber Construction in Switzerland. Trained as an engineer and carpenter, he is responsible for research and technical development in this timber construction company that has been lead-
ing the proliferation of advanced CNC timber fabrication.

As a fabricator, he brought a different perspective to the symposium. He discussed the office’s philosophy of bringing crafts experience and knowledge to advanced machining and building process. His discussed the necessity for having a complete understanding of material and fabrication processes in order to achieve efficient and high quality products. He showed examples of current projects in the office that employ advanced timber fabrication including the Clubhouse Haesley Nine Bridges project, South Korea by architects Shigeru Ban Associates and the Kilden Performing Arts Center, Norway by ALA Architects.

**Enric Ruiz-Geli, Cloud 9**

*Cloud 9: computation and fabrication*

Enric Ruiz-Geli founded Cloud 9, an interdisciplinary architectural studio in Barcelona in 1997. The Spanish architect and artist has been awarded the Research and Development Award of the Southern California Institute of Architecture (2008) and the Catalanian Premis MediAmbient for sustainable architecture (2009), among other awards. Known for their ‘Villa Nurbs’ in Empuriabrava, an organically formed, ecological and futuristic house, the office also recently completed the Media-TIC Building in Barcelona, which includes a high-tech membrane equipped with digitally controlled mechanisms that facilitate the absorption of sunlight.

Leading the panel session ‘Computation and Fabrication: How to Fabricate?’ Ruiz-Geli discussed the ways that Cloud 9 interface between architecture and art, and between digital processes and technological development. This panel session presented a variety of computational design techniques and discussed the new forms of collaboration that rise from this shift in material practice.
Azam Khan, Autodesk Research

Azam Khan is the Head of the Environment & Ergonomics Research Group at Autodesk Research. Khan work explores the modeling and simulation of physics-based generative design, air-flow and occupant flow in architectural contexts. With a focus on Building Information Modelling (BIM), his interest lies with the simulation, visualisation and validation of sensor-networks. In 2009, Azam founded and chaired SimAUD, the Symposium on Simulation for Architecture and Urban Design that aims to foster cross-pollination between the simulation research and the architecture research communities.

Leading the panel session ‘Computation and Simulation – How to Analyze’, Khan discussed different simulation approaches and ways in which simulation and analysis can become integrated into the early design phases. Khan illustrated these ideas with Project Dasher, a web-based application his team developed that helps to augment existing digital tools and design models using meter and sensor data. Project Dasher aims to demonstrate the value of integrating Building Information Modeling (BIM) and building instrumentation to provide building owners more insight into how existing buildings perform in real time and throughout the lifecycle of the building. They tested this in a case study at their own office in Toronto Canada where they are able to monitor real time performance.

Tobias Wallisser, LAVA
‘Towards an Architectural Agenda Based on Intrinsic Correlations’

Tobias Wallisser is an architect that has worked in the United States, Netherlands and Germany and for 10 years was an Associate Architect at UN Studio in Amsterdam. At UN Studio, he was responsible for many projects including the Stuttgart Mercedes-Benz Museum. In 2007, he co-founded LAVA (Laboratory for Visionary Architecture) with Chris Bosse and Alexander Rieck. LAVA is an architecture think tank with offices in Sydney, Shanghai, Stuttgart and Abu Dhabi. They gained recognition with the pro-
In his lecture, “Towards an Architectural Agenda Based on Intrinsic Correlations”, he presented his views about the ways that digital tools are impacting contemporary practice. He believes that parametric digital tools create opportunities for new criteria to be included in the design process. He argued that the parametricism in architecture has potentials for the profession not as a style, but rather as presenting a different way of working, for example using associative geometry means that form becomes derived from performance.

Sean Ahlquist is the founder of Proces2, and is currently a Research Associate and PhD Candidate of the Institute for Computational Design at the University of Stuttgart in Germany. Sean holds a Masters of Architecture degree from the Emergent Technologies and Design Program at the Architectural Association in London.

His work has spanned practice in both built and theoretical projects, instruction at institutions such as UC Berkeley, California College of the Arts and the AA as well as research and publication in computational design and fabrication techniques, including the forthcoming book entitled Computational Design Thinking, co-edited with Achim Menges.

In his presentation Ahlquist discussed his research on the simulation of tensile membranes. He presented a series of design tools developed for interactive form finding. Questioning the role of material performance he discussed how new tools have the potential for encoding mate-
rial properties for the specification, generation and articulation of tension active systems.

**Tristan Simmonds, Simmonds Studio**

Tristan Simmonds is a specialist designer and engineer with expertise in the design of complex and lightweight structures. He has been working as a specialist engineer for over 15 years and has developed a unique approach by combining digital computational techniques from the disciplines of mathematics, engineering and computer graphics to sculpt, design, engineer and fabricate complex and unusual structures. In addition to architectural projects, Simmonds has long been involved in projects with artists including Anish Kapoor and Antony Gormley, carrying out research and realising large and ambitious projects.

Simmonds discussed the process of realising the design of ‘Drift’ (2010) a large scale 40 m high installation develop for Antony Gormley. The project is a complex bubble matrix sculpture made of 16000 elements, weighing 16 tons suspended in the atrium of the Marina Bay Sands complex in Singapore.

Based on a human scale sculpture by the same name, Simmonds created the geometry for Drift from a complex polyhedral matrix generated by the interactive digital packing of spheres around a body form. In the presentation Simmonds discussed the process of designing, engineering and producing fabrication data for the project thereby exemplifying an implementation of a digital chain.
The fourth Digital Crafting workshop investigates the role of distributed agency within the design process. Algorithmic logic is used as platform for developing intensive modes of design formation. By exploring the methods that shape this logic, the workshop queries how concepts such as generative design and emergence can lead to new models of organisation and form in architectural design.

The workshop focused on the potentials of algorithmic techniques. Through simple rule-based systems, it is possible to create complex formations similar to behaviours and patterns found in the nature, such as flocking formations, swarm behaviours and plant growth patterns. These systems can then be used as generative processes in the development of form and organisation. The task of the designer then becomes more about setting up the rules and parameters that affect the form generating process, rather than explicitly defining the form itself. In this lies a possibility for the designer to focus on the tectonic logic of the project as a starting point, moving towards a bottom-up approach to architectural formation. Algorithmic methodologies enable architects to engage concepts of emergence, self-organisation and swarm intelligence in the design process, linking the work of architects and designers to developments in biology and computation.

The workshop introduced digital design tools to engage with self-organisation and swarm-based design. Using the Processing programming language, participants were introduced to some of the logics in programming that inform self-organising design systems.

The workshop asked:
- What are the potentials of using algorithmic methods in the design process?
- How can concepts such as ‘emergence’ and ‘swarm intelligence’ be operative in the design process?
- What are the implications for authorship within algorithmic design methodologies?
- How can tectonic concerns be seeded at a local level to facilitate the realisation of the project?
Workshop Leader: Roland Snooks

Roland is a Design Director and a Founding Partner of Kokkugia. He holds a Masters in Advanced Architectural Design from Columbia University where he studied on a Fulbright scholarship and is a graduate of RMIT University (B.Arch). Roland teaches graduate studios and seminars at the University of Pennsylvania, Columbia University and is the George Isaac Distinguished Fellow at the University of Southern California (USC). Roland’s design research is focused on emergent design methodologies involving agent-based techniques.
The fourth Digital Crafting Workshop ‘Generative logics: How to Grow’ was held at the Aarhus School of Architecture January 17-18 2011. The workshop was organised by Claus Peder Pedersen and Niels Martin Larsen from the Aarhus School of Architecture and invited guest workshop leader Roland Snooks from Kokkugia to lead the two-day workshop. During these days, the participants worked with agent-based scripting using the open source software ‘Processing’.

The first day kicked off with a crash course in ‘Processing’ introducing the basic structure and functionality of the software. From this starting point, a basic script was gradually developed to incorporate more complex capabilities exploring agent-based behaviour. These explorations were based on swarm theory as formulated by Craig Reynolds. Reynolds’ work with ‘boids’ describes how individual agents can form swarm behaviour by having each individual ‘agent’ adjust its position considering the separation, cohesion and alignment with other agents.

The second day was spent on further developing the agent-based scripts. These were expanded to incorporate interfaces that allowed for a more direct and intuitive manipulation of the various parameters controlling the agents. This led to a more general discussion on how to work with scripting as a design tool. The development also included discussions on how to interpret the animated agents and the resulting complex data structures into spatial configurations. This part of the workshop focused especially on using iso-surfaces as a way of creating formally coherent structures from clouds of points.

The workshop featured a presentation by Martin Tamke of CITA that presented his Lamella research project employing agent-based scripting in the design of a tectonic structure. The presentation was based on an exploration of the Zollinger construction principle, where short interlocking members create structurally stable constructions. Moving from top-down to bottom-up organisation, Martin discussed how a successful design strategy was developed by encoding the individual elements of the structure with instructions on how to attach to other elements.
The last part of the workshop explored how agent-based behaviours could be used in cellular automata scripts.

The presentations and discussions during the workshop related to the question of how designers can use agents-based scripts as a means to explore spatial and formal configuration and how these configurations can relate to material performance and structural logic. The workshop concluded with the opening of a student exhibition of spatial installations from the ‘Morphogenic Studio’ run by network members Niels Martin Larsen, Sebastian Gmelin and Claus Peder Pedersen at the Aarhus School of Architecture.
Could you describe what a generative design method is, and what characterises generative design compared to other types of design methods?

Generative design is a method where you do not design the object itself, but rather design the conditions from which the object emerges. The philosopher and social theorist Brian Massumi describes it as a shift from invention to orchestration. Instead of inventing the object you are orchestrating the system that underlies its formation. It is a way that you can draw many things in from outside of architecture. Many of the processes that underlie generative design come from science, such as biology and computation. It is not an attempt to try to make architecture scientific in anyway, but to open up enough space of abstraction between the author and the object to allow other things to squeeze their way in.

There is a false assumption that generative design and computational design are not intuitive – a belief that computational work is somehow objective. I think these methodologies are entirely subjective. I often paraphrase a friend of mine, Alisa Andrasek, who talks about generative design using the metaphor of training an animal. First of all you have this wild animal, and you do not know what it is going to do, it is unpredictable. Over time it learns from you, and you learn from it - a form of negotiation. It is a nice analogy.

What is the role of research in other fields, such as biology and computation, compared to generative design methods used in Kokkugia’s projects?

In some of the work we are doing, we are taking algorithmic logics from the sciences. The fundamental difference between the disciplines is that the sciences are interested in simulation and prediction. Essentially, attempting to understand the world. In architecture we are attempting to make new worlds. There is a necessity in science for correctness and there has to be a certain precision. Of course there is precision in computational design and generative design. The difference is that an algorithm for architecture only has to be
internally consistent. If it is consistent, and we can gain an intuitive understanding as to what it does, then we can use it for design. In the sciences, it is not enough for it to be consistent. An algorithm has to represent reality.

*Can you describe how swarm intelligence occurs in your work?*

I have been using swarm intelligence as the basis for my algorithmic research for almost ten years. Swarm intelligence is a form of self-organisation. The non-linear nature of agent-based design undermines the normative hierarchies that exist within architectural design.

Architecture is premised on a series of sequential design decisions that generally operate from a macro scale down to a micro scale. When you are dealing with swarm systems, the interactions are both levels at the same time. So it is not so much about inverting this relationship changing design into a bottom process, but instead everything can potentially be negotiated simultaneously just like an ecology. In Kokkugia...
we are interested in studying the organisational, structural and formal implications of these non-linear systems.

*In the workshop you described how generative design allows new types of hierarchies in the design process. How is this affecting your own work?*

With non-linear systems there is a chance for hierarchies to emerge, rather than being imposed from the outside. So instead of hierarchies being an a priori structure, you can talk about hierarchies as emerging from relationships. When we first started working with generative systems, there was a desire for everything to be generative and bottom-up. Increasingly we are realising that there are a lot of problems within architecture that are not complex problems, and therefore do not need a generative or emergent process to respond to them.

One way of defining emergence is through the self-organisation of hierarchy. To establish that something has emerged, there has to be an apparent order, which implies some level of hierarchy. Consequently hierarchy is one characteristic, or trait, that we search for. In considering Stephen Wolfram’s cellular automata, and especially rule 110 or rule 30, it is obvious that they do not have imposed hierarchies, but there is a certain repetition. Manuel DeLanda talks about this in his writing on meshworks and hierarchies. He makes the claim that there is no such thing as the pure meshwork or the pure hierarchy, but that they are always nested within each other to some degree.

*Interview by Niels Martin Larsen, Aarhus School of Architecture*
Generative Design Thinking
January 19th, 2011

Presenters
Roland Snooks, Architect and Founding Partner Kokkugia, New York
Jan Henrik Hansen, Architect and Founding Partner Whist.ch, Zurich
Christian Derix, Architect and Head of Computational Design Research Group, AEDAS Research, London
Åsmund Gamlesaeter, Architect and Senior Designer, AEDAS Research, London

Generative processes based on algorithmic techniques offer new possibilities for the design process. These techniques enable the exploration of spatial and structural configurations that are inaccessible through traditional architectural design methodologies. Using these design approaches, new potentials for informing and specifying architectural space become available. These also create challenges to traditional notions of representation, of authorship, of control of the design intent and of outcome. The seminar discussed the potentials, strategies and challenges of algorithmic design approaches.

This seminar asked:
- How can we define external design influences and how can digitally encode and compute these?
- What precedence exists for designing with generative processes and how are current examples progressing this approach?
Christian Derix founded the Research & Development group at international design practice Aedas architects in 2004. He leads the Computational Design Research group (CDR) that develops computational design applications for generative and analytical design processes in architecture with an emphasis on properties of space and human occupation.

Can you explain your work at the Computational Design and Research group (CDR) and how it relates to the idea of emergence as a design strategy?

The work of Aedas’s CDR has a long history of research into ‘emergence’ as a design strategy. The founding members – myself and Pablo Miranda – were both students and later tutors at the MSc Computing & Design of the Centre for Evolutionary Computing in Architecture at University of East London where Paul Coates taught algorithmic design and the notion of emergence since 1991. The CDR now has five members: Christian Derix, Åsmund Gamlesæter, Lucy Helme, Prarthana Jagannath, and Anders Holden Deleuran.

Emergence as a design strategy can often be a misguided concept, as in many of the ‘swarm intelligence’ approaches where the ‘emergent’ pattern is a formal means to its own end. Emergence in a design context has to be identifiable as a condition that derives from the constrained design system. These conditions usually do not represent whole patterns, but rather small situations within a design state. An example could be an un-premeditated neighbourhood configuration in a land-use allocation simulation. In this case that larger pattern might be new but not emergent, as the system was specified by the designer.

At CDR, emergence as a design method refers to a search mechanism translated via meta-heuristic and algorithmic processes. These are often based on self-organisation principles and help to search a concise design space. If the design space is under-constrained, vague or purely formal, then it is hard to identify, measure and use the novel conditions in a meaningful way. This, in turn, leads to the alienation of design team colleagues who have no vehicle for evaluation.
Can you explain a recent CDR project and how it relates to ideas of Digital Crafting, particularly the idea of generative design thinking? What new design directions are possible for architects using these technologies and processes?

When thinking about ‘crafting’ and ‘generative’, CDR thinks of the autonomous design processes that the designer can interfere with, but not determine. Based on these ideas, we have recently developed a set of design simulations for the Fraunhofer Institute to test potential new scenarios for spatial planning of buildings, called Virtual Building Simulator (VBS). The VBS allows the user to generate building mass and layout configurations with ‘emergent’ 3D circulation, while being immersed in and tracked inside the virtual space of the ‘generative system’. This enables the designer to participate in the generative system in real-time and to craft the building mass, without changing the autonomy of the generating process or determining the outcome. The system not only organises the spatial configuration by areas and adjacencies, but also searches for circulation diagrams with potential new hybrid functions, resulting from the synergy between areas.

The VBS project demonstrates how generative processes can suggest spatial programs and
lead to unexpected results. This approach sits between the now generally assumed parametric design approach - where all relations are specified explicitly and the process is mostly not self-generating- and a more orthodox self-organisation approach such as swarm systems that are left un-constrained. To employ ‘generative design thinking’, design teams must learn to communicate and integrate with computational designers who craft such processes. This entails a specification of the design intentions via behavioural diagrams and desired states, leaving behind detailed visual representations and formal sketches of the resulting building forms.

*How have generative processes influenced your design process? How have your ways of working changed over the years and how do you imagine a future workflow?*

When we started in academia, two approaches to generative design dominated: on the one hand the purist analogy approach, ie the ‘swarm’ or other such metaphoric representations which are taken quite literally, and on the other hand, the full system approach, which attempts to integrate as many parameters as possible into a simulation, i.e. over-constrain the process. In the beginning, we designed generative systems that seemed to do it all, from topological planning of layout, to parametric geometric embodiment, to optimisation and so forth. Several purist algorithms were integrated with a large amount of data and criteria to create closed ecologies. We realised that after a while this excludes the designer’s skill siting them outside the actual design process. If the logic of simulations are opaque and in-accessible (the ‘black box’), it pushes the designer to either accept the outcome without understanding it or abandon it altogether.

This makes it next to impossible to visualise the process in one simple transparent representation. Since about 2006 we therefore design the systems as multiple concise generative and analytical models that are limited to distinct spatial and user phenomena, which the designers then can assemble into flexible workflows that integrate them in the search for states.
WORKSHOP 5
22.- 24.08.2011 WORKSHOP AND SEMINAR

TEXTILE LOGIC: HOW TO BRACE

KOLDING SCHOOL OF DESIGN, DEPARTMENT OF PRODUCT DESIGN

WORKSHOP GUEST: SEAN AHLQUIST
The fifth and final Digital Crafting workshop investigated the intersections between textiles design and membrane architecture. Textile design is a form of material design. Forming the textile structure and composing different yarns enables the fabrication of highly specialised materials designed to suit a specific performance and use. The aim for the workshop was to develop our own bespoke, complex structured and materially graded textiles for use in textile architecture. The workshop investigated how the tradition of working with textile membranes can be reconsidered with respect to architecturally designed engineered materials.

The workshop explored computational design tools as a means of designing, simulating and optimising tensile membranes. By interfacing these bespoke design systems with CNC knitting machines, the aim was to generate our own bespoke textiles designed directly in respect to the performance criteria identified in the simulation.

The workshop asked:
- How can we generate feedback between the global (the scale of the membrane) and local (the scale of the material) behaviour of the surface?

- How can these feedback loops be used to inform the translation between the relative shape and force description described computationally and the complex material performance in a graded material?
Workshop Guest: Sean Ahlquist

Sean Ahlquist is the founder of Proces2, and he is currently a Research Associate and PhD Candidate of the Institute for Computational Design at the University of Stuttgart. Ahlquist holds a Masters of Architecture degree from the Architectural Association in London, Emergent Design and Technologies Programme. He has published, lectured and led workshops widely on computational design and fabrication techniques, including the forthcoming book entitled Computational Design Thinking, co-edited with Achim Menges. Current research involves the development of computational methods which impose material characteristics through the calculation of fundamental physical behaviors. This involves the cross-disciplinary study of biology, biomimetic and structural engineering, material science and computation.

The Digital Crafting Network thanks Kolding School of Design for hosting the workshop. Thank you to Vibeke Rübsberg, Joy Boutrup and Helene Jensen.
The fifth and final Digital Crafting workshop ‘Complex Membranes and the Variegated Material’ was held at Kolding School of Design August 22-24 2011. The workshop was organised by Mette Ramsgaard Thomsen of CITA and textile designer Vibeke Riisberg from the Institute of Product Design at Kolding School of Design. The organisers invited Sean Ahlquist, to lead the two-day workshop. The workshop involved a multi-disciplinary team with different expertise including Mette Ramsgaard Thomsen, an architect working with digital tools for textile specification, Joy Boutrup, a textile engineer, Vibeke Riisberg, a textile designer and Helene Jensen, a knitting expert.

In the workshop the participants used digital tools to create computational models using minimal surface software. This process explored ideas of material design and ways of using digital tools to tune material performance. Instead of using a pre-fabricated uniform material, the workshop explored the interfacing with CNC knitting machines to develop their own non-uniform or ‘graded’ materials. The resulting materials then hand stitched together and assembled into frames so that their textures and properties could be tested and observed.

The aim of the workshop was to investigate the potentials of integrating textile craft traditions with computational design tools to understand the potentials for designing new materials which have designed performances. Through the development of bespoke, complex structured and materially variegated textiles, a new way of thinking about performance, assembly and material connections can be developed. During the workshop, participants discussed ideas about the relationship between simulation and material specification and what kind of feedback loops are needed to enable this new design practice. In the workshop the possibility to develop quick material tests and prototypes allowed participants to examine ideas at 1:1 and then refine their designs, creating a creative feedback loop.
As the workshop guest leader, what were your main intentions with ‘Complex Membranes and the Graded Material’?

The intention with the workshop was to examine the relationship between a structured surface and its material composition. Often, with structures at an architectural scale defined purely by tensile forces flowing through textile (membrane) elements, material composition is considered homogenous. This is almost a necessity in a design-oriented process because the complexity of the structural system imposes the challenge of simultaneously needing to resolve structure and geometry. The workshop intended to survey variation at the material level and its relation and ramifications to structure as it defines a specific geometry.

What is your understanding of ‘graded materials’?

In the context of the workshop, ‘graded materials’ was understood as the differentiation of a material’s internal structural logic. The ramifications of such variation manifested itself, secondarily, as a ‘graded’ structural system. This introduced an interesting contrast for the understanding of the term ‘structure’. In a textile, structure is the term for the fiber composition. This is of course intimately connected to making, but primarily about the precursor – the logic by which fibers are interwoven. Comparatively, in architecture, we refer to structure as the resultant artifact. While it refers integrally to the assembly of all elements, structure is the repercussion of materiality, assembly and imposition of internal and external forces. By examining graded materials and the ‘bracing’ of such the workshop investigated the relation of these two ends of the spectrum of ‘structure’.

What were the main areas of experimentation in the workshop and what were the most successful outcomes of the workshop?

While the information-based process of computational modeling to CNC fabrication and assembly has been quite thoroughly tried, tested, and arguably perfected, what this workshop introduced were moments at which the consideration of material behaviour jostled that
routine. Behaviour resides at multiple levels of the system, from the micro level in the material characteristics of the individual fibres, to the structural patterns within the knitted textile, and ultimately to the macro level of tension forces acting across the continuous textile surface. It was particularly jarring that in the process of fabricating the structure of the textile, behaviour was activated because of the friction of the bi-directional knitted fibres.

This behaviour was non-uniform because of the variegated patterns being utilised. Thus, from the fabrication step, a material element was generated that did NOT match the shape that was entered in to the CNC fabrication process. While the focus was primarily on orchestrating behaviour in form, we found that behaviour needed to be investigated even at the level of fabrication.

*In the group discussions, we talked about how these ideas begin to suggest new ideas and workflows relating to the simulation and modelling of material performance in architectural practice. How do you reflect on these ideas?*

A contribution from this and other Digital Crafting workshops can be seen most fundamentally in the realm of how it changes practice. What is interesting is that we are entering a shift from design in representation to design through simulation. This is also a different way of conducting simulations, compared to an engineered approach. The engineer, in general terms, utilises simulation as a proof. In the workshops, we used simulation as a design tool to engage in an explorative process. Here we are taking advantage of the verifiable principles to be able to interrogate higher levels of performance in function which in turn can be realised through relations between materiality (composition) and materialisation (fabrication). The practice of architecture then includes the implementation of specific principles, rather than what is more often the case, the generalisation of abstract notions and assumptions of a functioning whole that are often incorrect. Just like in the workshop where we learned that when engaging material specificity through design exploration, our assumptions on the performance of the material were almost always wrong.
**Designing with material specificity is not currently common in architectural practice, why do you think it is important and how does it relate to your own research?**

Once you begin considering material as an aspect of performance, the design of its specificity is absolute. This is ever-present in the design of lightweight structures where there is an integral relation between the definition of a geometry and its performance – primarily as a structural system. Where this becomes interesting is in the attempt to define multiple capacities via the specification of material. It not only involves defining, or selecting, the characteristics of the material itself, but also generating its position, and determining its contribution to the global form. This then introduces differentiation as a necessary variable in design rather than an aesthetic choice. Here, variation provides the only avenue to resolve multiple functionalities. Such an approach is exemplified in the on-going research at the ICD with ‘Deep Surfaces’ – morphologically articulated tension structures.

To advance the spatial opportunities with tension structures in thermal, acoustic, and luminance modulation, the possibilities in geometric variation and relation to material performance have to be explored. The determination of such potentials defines a new set of principles which can then be generatively explored to realise multi-functionality at the global scale of the system.
Workshop 5 Seminar Topic

**Textiles and Fibre-based Materials in Architectural Construction**

24 August 2010

Presenters

**Joy Boutrup**, *‘Scales of Performance: fibres, yarns and textiles’*
Textile Engineer, Associate Professor, Kolding School of Design, Denmark

**Johan Bettum**, *‘The Material Geometry of Fibre-Reinforced Polymer Matrix Composites’*
Professor of architecture and Program director of the Städelschule Architecture Class, Germany

**Julian Lienhard**, *‘Bending Active Membrane Structures’*
Research Associate and PhD Candidate at the Institute of Building Structures and Structural Design (ITKE), University of Stuttgart, Germany

**Sean Ahlquist**, *‘The Computational Perspective’*
founder of Proces2, Research Associate and PhD Candidate at the Institute for Computational Design, University of Stuttgart, Germany

With work-in-progress presentations from:

**Guenther H. Filz**, Assistant Professor, Institute for Structure and Design, University of Innsbruck, Austria

**Delia Dumitrescu**, Textile Designer, PhD Student, Swedish School of Textiles and Department of Computer Science and Engineering, Chalmers University of Technology, Göteborg, Sweden.

**Karen Marie Hassling**, Textile Engineer, Researcher, Technical University of Denmark.
The seminar examined the use of fibre-based materials in architecture. During the last decade, textiles and fibre-based materials have undergone dramatic developments resulting in their use and implementation in new contexts. These have spanned a broad range of scales, including the extremes of geo-textiles and biotextiles. Textile design is incorporating existing technologies and inventing new ones. At the same time, developments in polymers and reinforcing materials are leading to new opportunities for computational design and processing methods for fibre reinforced composites. These in turn provide designers with new means of engagement and control.

The seminar held a dual focus. Firstly, it brought together researchers from architecture, engineering, and textile design to discuss the traditions by which textiles and fibre-based materials have been understood as an architectural material. Secondly it presented a new perspective for experimental textile design in the built environment. By deliberately expanding the discussion to include soft textiles as well as consolidated fibre reinforced composites such as fibre glass, the aim was to foster a discussion of the parallels and differences in these two material design fields.

The seminar asks:
- With the Stuttgart tradition of designing and calculating membrane structures having led to a reinvention of the use of textiles in architecture in the mid 20th century, what are the new perspectives in these traditions and how can they embrace questions of complex geometry and material grading?

- The recent focus on fibre reinforced composites presents architecture and the built environment with a new engineered material that can be devised and developed in respect to its performance. How can designers work affectively with composites and what are their future uses?

- What are the environmental consequences of these new materials and how can we work in a sustainable fashion?
Julian Lienhard earned his Diploma in Civil Engineering at the University of Stuttgart in 2007. He is currently writing his PhD on bending-active structures at the Institute of Building Structures and Structural Design (ITKE), supervised by Prof. Jan Knippers. He is leading the German ministry funded research project ‘Pliable Surface Structures on the Basis of Bionic Principles’ which was recently awarded the Techtextil Innovation Prize 2011. In 2008, Julian founded the engineering and design practice studioLD.

*In your lecture, you discuss ‘form-active structures’, can you elaborate on this idea as it relates to your own work with ‘bending-active structures’?

Form-active structures are the newest category of structural systems where textile or foil materials develop significant structural capacities. Based on the combination of pre-stress and double curvature, the membrane material is able to not only work as cladding on an existing structure, but to become a central component of the structural system. This allows a high level of integration and at the same time long spanning and lightweight structures.

Since the shape of such a membrane structure is developed in a physical or digital form-finding process, the designer only has limited influence on the resulting surface geometry. It seems like some contemporary architects want to have a more direct influence on the shape, motivated by design ideas or supplemen-
tary functions they want to assign to the surface. Unfortunately, this often leads back to the membrane acting merely as a cladding on a what becomes a significant steel structure. Introducing elastically bent rods in the surface element opens completely new possibilities in the interaction with the form-finding process and presents formal freedom.

At the same time, we are looking at new steps in which we are integrating the primary structure into the membrane surface. We call such structures that base their geometry on the elastic deformation of initially straight or planar elements ‘Bending-Active’.

*How does this relate to the ICD/ITKE Research Pavilion and your role doing finite element simulation of the deformations?*

In the research Pavilion ICD/ITKE, developed with Prof. Achim Menges at the ICD, University of Stuttgart, we elaborated the potentials of such bending active structures in a digital design process. We were able to show the great potentials of bending active-structures in creating complex geometry based on planar building components and were also able to prove a stiffening effect based on the bending pre-stress.

In other projects, we have shown how this approach may also be integrated in form-active structures and even kinematic structures. In all of these projects, the aspect of reliable material data such as the young’s-modulus (a measure of the stiffness of an elastic material) and precise finite-element simulation of the bending deformations were the key for a successful realisation. The material testing and simulation procedure is however still very time consuming. We are currently working on refining our routines and finding ways of directly integrating the finite element simulation in the design process.

*How do you see material performance simulation giving the designer more feedback for the design process?*

In Bending-Active structures, the material performance is inseparable from the resulting geometry. Material behaviour therefore gives the designer important feedback in this particular approach. As much as this may be stimulating for the design process, it also requires a certain commitment to the necessity for extensive simulation. We therefore work a lot with scaled physical models made of the intended materials (here Glass Fibre Reinforced Polymer) for extensive material study and design investigation.

In Kolding, the discussion took a very nice turn at the end where we contemplated the potentials of integrative design approaches; which is one of the greatest potentials of Digital Crafting. Our discussion related to potentials to expand and redefine the role of the architects and engineers in these procedures.

On the one hand, we have to broaden the set of skills to foster the close collaboration and communication with each other, on the other hand, we are asked to input a high degree of specialised knowledge. Even though a lot has been said about these new design procedures, I still have questions about my role as an engineer within such a community. It was very good to have Jan Søndergaard, design principle and partner of leading Danish architectural practice KHR, join our discussion. We need such experienced architects to give us feedback and to give a kind of reality check.
CITA, Krydserum, Akustikmiljø
SYMPOSIUM 2
25.11.2011

CONSEQUENCES

CITA
ROYAL ACADEMY OF FINE ARTS, SCHOOL OF ARCHITECTURE, DESIGN AND CONSERVATION
Today digital design technologies have become ubiquitous tools informing all parts of the design practice. From the generation of early design intent, through to environmental simulation and structural analysis and finally fabrication, we are now witnessing a maturing of the digital design chain. The second Digital Crafting symposium questioned the consequences of this newly established digital platform. Inviting presenters from the fields of architectural design, theory, engineering, and fabrication the aim for the symposium was to discuss the real added values that these new design processes present.

The symposium invited six speakers from leading international architectural design practices and academic research to discuss their understanding of where integrated digital design is heading. By reflecting on how these new interdisciplinary workflows are impacting the boundaries of the professions, the symposium asked controversial questions of what happens to design control, ownership and the economic and legislative responsibilities of building practice.

The symposium was structured in 3 sessions: Session 1, ‘Consequences for Making’ discussed the impact on fabrication and the true relevance of positioning crafting as a generator for design intent, Session 2, ‘Consequences for material practice’ discussed how the integration of engineering and design are leading to new structural solutions and Session 3: ‘Consequences for design practice’ asked how these developments are implemented in contemporary working practices.

The three sessions were punctuated with short presentations of the 5 workshop-seminars allowing audience to gain insight into the breadth of the Digital Crafting network activities.
Massimiliano Fuxas with Knippers Helbig - Advanced Engineering
**Jan Knippers**, Knippers Helbig Advanced Engineering / ITKE
*‘Digital Strategies for Non-Standard Construction’*

Jan Knippers studied civil engineering at the Technical University in Berlin. He founded Knippers Helbig Advanced Engineering in Stuttgart (2001) and New York (2009) with Thorsten Helbig. He is Professor and Head of the Institute for Building Structures and Structural Design (ITKE) at the Faculty for Architecture and Urban Design at the University of Stuttgart in Germany. His research and teaching focuses on highly efficient building structures and the use of innovative building materials.

In his lecture, he talked about the difference between architectural and engineering approaches in design, and how parametric tools are creating new forms of practice, allowing flexibility and design opportunities for engineering. He illustrated his ideas with examples including the office’s work on the Baoan International Airport in Shenzhen China, which has a parametric three dimensional folded aluminium façade and parametric free form steel structure.

**Fabio Gramazio**, Gramazio & Kohler

Fabio Gramazio is the co-founder of design office Gramazio & Kohler in Zurich. With Matthias Kohler, their recent works include the contemporary dance institution “Tanzhaus Zurich” as well as the façade for the winery Gantenbein in Fläsch. Part of their professional activities includes developing innovative construction and material solutions.

Gramazio’s activities relating to his Professorship for Architecture and Digital Fabrication at ETH Zurich are concentrated on the development of fabrication processes for the additive production of highly informed, non-standardised architectonic products. An industrial robot is used for research and teaching, permitting the direct construction of building components. In his lecture, Gramazio contextualized his work with Matthias Kohler in using robots, which are complex industrial tools not normally used in practice, to achieve architectural experimentation. His presentation linked ways that architects can use digital tools to rethink construction, design the process of construction and
achieve “material sensuality”. He explained his ideas of “digital materiality” using examples from his research at ETH.

**Paul Ehret, Gehry Technologies**

*‘Global Project Delivery’*

Paul Ehret is a Paris-based designer at Gehry Technologies Europe since 2007. GT Europe provides technology and services to European clients so that they can increase their professional creativity; reduce project risk, waste and costs; and create more innovative, life-enhancing buildings. At Gehry Technologies he has led digital teams on projects such as Kapsarc for Zaha Hadid Architects, the Louis Vuitton Foundation and the Luma Foundation for Frank O. Gehry, some tower projects for Skidmore Owings and Merrill. He is teaching Digital Design and Production in the Ecole Speciale d’Architecture (Paris) and at the Ecole Polytechnique de Lausanne (EPFL).

In his lecture “Global Project Delivery” he talked about how the office collaborates with different project partners at different stages, and how the sequence of design and construction is changing with new technological advances such as increased geometric analysis and control during the design stages. He illustrated discussion of these new design processes with projects including the new Latoll Retail Park with architects AAVP for which Gehry Technologies provided specialty design support for the design to production of 60,000 square meters of custom perforated aluminium panels.

**Marta Malé-Alemany, IAAC**

Marta Malé-Alemany is a registered architect from Barcelona, and the acting director of the Institute for Advanced Architecture of Catalonia (IAAC) in Barcelona since July 2011, after co-directing its Master Program for several years. She has taught architectural design in several well-known Universities in the US (MIT, U.PENN, UCLA, SCI-ARC, and others) and been a Course Master Tutor in the Design Research Laboratory (DRL) at the AA (Architectural Association) in London.
Her academic research focuses on the conceptual and material opportunities that emerge from the use of digital design and fabrication technologies for the production of architecture. Outside of academic environment, Marta Malé-Alemany directs her own professional studio in Barcelona and has curated several exhibitions on digital fabrication subjects. From the studio she develops her own projects and collaborates with other practices as a consultant for specific projects, in areas that range from the analysis and concept development of parametric design proposals to the application of digital technologies for the materialization of complex forms.

Marta Malé-Alemany graduated from ETSAV-UPC (Barcelona, 96), holds a Master Degree in Advanced Architectural Design from Columbia University (New York, 97) and is currently a PhD candidate at the ETSAB-UPC (Barcelona), investigating the potential of large-sale rapid manufacturing technologies to innovate building construction.

**Antoine Picon, Harvard University**

*Emergent Reality or Regressive Utopia*

Antoine Picon is the G. Ware Travelstead Professor of the History of Architecture and Technology and Co-Director of Doctoral Programs (PhD & DDes) at the Graduate School of Design at Harvard University. He teaches courses in the history and theory of architecture and technology. Trained as an engineer, architect, and historian, Picon works on the history of architectural and urban technologies from the eighteenth century to the present. He is the author of numerous books, including “Digital Culture in Architecture: An Introduction for the Design Profession” (2010) which offers a comprehensive overview and discussion of the changes brought by the computer to the theory and practice of architecture.

He discussed the possibilities of collaborative design practice and argues that architects should go beyond thinking about the formal output of their designs using new digital tools and actually seek to uncover the true politics of digital design and digital fabrication.
Reinhard Kropf, Helen & Hard

‘Helen & Hard’

Reinhard Kropf is an Austrian architect, who studied at the Technical University of Graz and then AHO Oslo in Norway. With partner Siv Helene Stangeland, he co-founded design office Helen & Hard with offices in Stavanger and Oslo. Kropf teaches at Kansas State University, AHO Oslo, ESA Paris and HUST Wuhan, China.

His lecture described a series of projects including the Ratatosk Installation (2010). This project began with the designers selecting certain ash trees, cutting them at their base and splitting them, and then 3D scanning, digital modeling, simulating, and CNC milling these trees and then reassembling them at the Victoria and Albert Museum in London as public sculpture.

Using digital tools to mill the specifically chosen timber pieces, rather than using a uniform or mass produced timber component, allowed the designers to consider the material qualities such as fiber direction, formation of branches as well as the performative potential of the tim-
Lamella Flock, CITA
Aron Fidjeland

**Affiliation:**
B.Arch. CITA, Centre for Information Technology and Architecture, Royal Academy of Fine Arts, School of Architecture.

**Contact:**
aron.fidjeland@gmail.com

Aron is a student at Kunstakademiets Arkitektskole, department 2. He has just ended an internship at the Centre for Information Technology and Architecture (CITA) in Copenhagen Denmark.

Anders Holden Deleuran

**Affiliation:**

**Contact:**
Anders.Deleuran@aedas.com

Anders Holden Deleuran holds a M.Sc. Eng. in Architecture & Design from Aalborg University, specializing in Digital Design within a broad scale of projects including architectural, industrial and graphic design. He completed a course in Advanced Visualisation at Umeå Institute of Design, Sweden in 2007.

Anders has worked at CITA as a research assistant and designer, and currently works at international design practice Aedas. As a Computational Design Researcher within the R&D Team, he is researching the computational metrics of spatial occupancy, description and simulation.

Anke Pasold

**Affiliation:**
AREA

**Contact:**
anke@studio-area.net
www.studio-area.net

Anke Pasold, Dipl.-Des. in architecture and interdisciplinary design from CoFA/UNSW in Sydney, the Academy of Fine Arts in Stuttgart and the School of Media and Design (ZKM) Karlsruhe and M.Arch. in ‘Genetic Architectures’ from the EsArq, UIC, Barcelona, is currently lecturer and tutor at IHK and KFA in Copenhagen with a focus on the implementation of digital design.

Anke is the co-founder of the research based architectural practice AREA, which explores material properties, design methods, generative systems, and techniques with performative environmental architectures as results.

Antoine Picon

**Affiliation:**
Graduate School of Design Harvard University

**Contact:**
apicon@gsd.harvard.edu
www.gsd.harvard.edu/#/people/antoinepicon.html

Antoine Picon is the G. Ware Travelstead Professor of the History of Architecture and Technology and Co-Director of Doctoral Programs (PhD & DDes) at Harvard’s graduate school of design. Trained as an engineer, architect, and historian, Picon works on the history of architectural and urban technologies from the 18th century to the present. His book, *Digital Culture in Architecture: An Introduction for the Design Profession* (2010) offers a comprehensive overview and discussion of the changes brought by the computer to the theory and practice of architecture.

Annica Ekdahl

**Affiliation:**
CITA, Centre for Information Technology and Architecture Royal Academy of Fine Arts, School of Architecture

**Contact:**
Annica.Ekdahl@karch.dk

Annica is a student at Aarhus School of Architecture, at the moment doing an internship at the Centre for Information Technology and Architecture (CITA) in Copenhagen Denmark.

Asbjørn Søndergaard

**Contact:**
asbjorn.sondergaard@aarch.dk
www.fluxstructures.net

Asbjørn Søndergaard is an architect working in the field of digital fabrication in its relation to architectural design. He is educated from Aarhus School of Architecture, and founder of DesignCompute, a design firm framing architectural design experimentation in the field of structural optimization and computational tools. His research based work focuses on morphogenetic processes and the development of novel structural logics in relation to numerical fabrication techniques. In collaboration with civil engineer Per Dombernowsky, he has been responsible for the elaboration of structural optimization case studies and design of a full scale prototype structure within the collaborate research project Unikabeton.
Åsmund Gamlesæter graduated with an MArch from NTNU, Norway in 2006. After completing his studies he started working with Pablo Miranda Carranza on Spoorg, a project by the architecture group Servo, for which they were responsible of the interaction design. Åsmund has worked as a Computational Design Researcher at Aedas since May 2007. In this time, he has been investigating new forms of furniture design, architecture and urban planning through code. This has resulted in a set of tools and sketches implemented in projects both inside and outside Aedas.

Aurélie Mossé is a textile designer and researcher working with responsive materials and digital technologies. She is about to complete a PhD in Tectonic Textiles at CITA, in collaboration with TFRC under the supervision of Carole Collet and Mette Ramsgaard Thomsen. At the intersection of textile design, architecture and smart technologies, her research is practice-based and design-led. It investigates how the design of self-actuated textiles can contribute to a domestic culture in which technology cultivates a relationship of interconnectivity with nature.

Azam Khan is the Head of the Environment & Ergonomics Research Group at Autodesk Research. His current research explores modelling and simulation including physics-based generative design, air flow and occupant flow in an architectural context, and simulation visualisation and validation based on sensor-networks. In 2009, Azam founded and chaired SimAUD, the Symposium on Simulation for Architecture and Urban Design to foster cross-pollination between the simulation research and the architecture research communities.

Brady Peters is a Phd Fellow at CITA. His PhD project, “Complex Surfaces: Sound and Space defining Surfaces for Architecture,” studies the interfaces between architecture, acoustic science and engineering. Previously, he was an Associate Partner at Foster + Partners in London, working in the Specialist Modelling Group, the office’s internal research and development consultancy. He specialises in digital design, parametric modeling, computational techniques, performance-driven design, and the communication and construction of complex geometry.

Christian Derix founded the Research & Development group at Aedas architects in 2004. He leads the Computational Design Research group (CDR) that develops computational design applications for generative and analytical design processes in architecture with an emphasis on properties of space and human occupation. Recently, the work of CDR has been shortlisted for various design prices and research awards like the Compasso d’Oro in Italy and won the commendation of the President’s Medal for Practice Research of the Royal Institute of British Architects [RIBA].

Christoph Schindler is the co-founder of schindlersalmerón, a design studio that develops parametric objects at the interface of architecture and product design. Well known examples of their approach are the parametric coat rack “Kleiderleiste”, one of very few customisable products in the market, and the awarded wood construction principle “Zipshape”. The firm is interested in both digital fabrication and traditional workmanship. Schindler’s experience ranges from intelligent design objects to developing realization strategies for large complex building projects in his former position at ETH Zurich and designtoproduction.
Claus Peder Pedersen is an architect that works as a researcher, educator and occasional practitioner. His research is centered on relations between representation, geometry and architecture with focus on digital tools. He pursues these interests through design based as well as academic research. Claus is educated at the Royal Academy of Fine Arts, School of Architecture. He has a ph.d. in architecture from the the Aarhus School of Architecture, where he is Head of Research and holds a position as associate professor at the Institute of Architecture. He was a founding partner in the architectural office TRANSFORM and is currently partner in the cross disciplinary practice Blankspace.

Delia Dumitrescu has an architect diploma from “Ion Mincu” University of Architecture and Urbanism, Bucharest, Romania. In 2008, she finished her master degree in textile design at The Swedish School of Textiles, University of Borås, Sweden. Since 2008 she is a Phd student at the Swedish School of Textiles and at the Department of Computer Science and Engineering Chalmers University of Technology, Göteborg.

Dave Stasiuk received his Master in Architecture from the Rensselaer Polytechnic Institute School of Architecture in Troy, NY is 2010. He returned to university to study architecture after a career implementing information modeling, data management and strategic analysis in the sales and marketing division of a U.S.-based pharmaceutical company. His background and interests led him to data-driven parametric design research in his studies. In Copenhagen, he has collaborated with CITA both teaching workshops and developing projects. He is also currently working as a specialized digital modeling consultant for Method Design, a New York based firm.

Delia Dumitrescu

Affiliation: Swedish School of Textiles, University of Borås Department of Applied Information Technology, Chalmers University of Technology, Göteborg

Contact: Delia.Dumitrescu@hb.se
www.hb.se

Claus Peder Pedersen

Affiliation: Aarhus School of Architecture

Fabian Scheurer graduated from the Technical University of Munich after studying computer sciences and architecture and worked as assistant at the CAAD group of TU-Munich, as software developer at Nemetschek Programmsystem GmbH, and as new media consultant for Eclat AG in Zurich. His work seeks to interface the abstract order of digital systems with the creative chaos of design. In 2005 he co-founded designtoproduction as a research group at the ETH. Since 2006 he is an associate in the company of the same name.

Dave Stasiuk

Affiliation: CITA, MArch I.

Contact: dave.stasiuk@gmail.com

Delia Dumitrescu

Affiliation: Swedish School of Textiles, University of Borås Department of Applied Information Technology, Chalmers University of Technology, Göteborg

Contact: Delia.Dumitrescu@hb.se
www.hb.se

Enric Ruiz-Geli has an architect diploma from “Ion Mincu” University of Architecture and Urbanism, Bucharest, Romania. In 2008, she finished her master degree in textile design at The Swedish School of Textiles, University of Borås, Sweden. Since 2008 she is a Phd student at the Swedish School of Textiles and at the Department of Computer Science and Engineering Chalmers University of Technology, Göteborg.

Fabian Scheurer

Affiliation: designtoproduction

Contact: scheurer@designtoproduction.ch
www.designtoproduction.ch

Contact: http://www.ruiz-geli.com
http://www.e-cloud9.com

Enric Ruiz-Geli and his interdisciplinary architectural team Cloud 9 in Barcelona work at the interface between architecture and art, digital processes and technological material development. Their multifaceted projects include stage sets and buildings, installations and industrial products, and are realized together with various collaborative partners. Cloud 9 is committed to the use of new technological developments and the performative character of architecture, which creates intelligent structures in emulation of nature.

Fabio Gramazio

Affiliation: ETH / Gramazio Kohler architects / Zurich

Contact: gramazio@gramaziokohler.com
www.dfab.arch.ethz.ch
www.ita.arch.ethz.ch

Fabio Gramazio and Matthias Kohler are joint partners in the architecture office Gramazio & Kohler in Zurich. Their recent works include the new Christmas illuminations in the Zurich Bahnhofstrasse, the contemporary dance institution “Tanzhaus Zurich” as well as the façade for the winery Gantenbein in Fläsch. Their research activities at the professorship for architecture and digital fabrication at ETH in Zurich are concentrated on the development of fabrication processes for the additive production of highly informed, non-standardised architectonic products.
Felecia Davis is a PhD candidate in the Design and Computation Group at MIT. She has been trained as an architect at Princeton University, and engineer at Tuft University and has been exploring intersections between architecture and textiles to design soft buildings that use the pliability of fabrics.

Guenther Filz, born 1973, received his Diploma degree and PhD in architecture with distinction from the University of Innsbruck, Austria. He worked amongst others for Eisenman Architects, NYC, before becoming Assistant Professor at the Institute for Structure and Design, with Prof. Eda Schaur (former Head of IL, Stuttgart) in 2002. His main area of research is related to self-organising processes, lightweight and mainly membrane structures.

Hauke Jungjohann is a Director of Knippers Helbig’s New York office. Knippers Helbig is a structural engineering consultancy based in Stuttgart (Germany) and New York with a focus on freeform structures, facades and operable building envelopes. Hauke’s interests include implementation of parametric design tools in the process of structural analysis, the introduction of form optimisation algorithms in the building design phase and digital information transfer through the entire design and construction process.

Isak Worre Foged is MSc.Eng.Arch. from the Institute of Architecture & Design (A&D), Aalborg University and M.Arch. from the EsArq, UIC, a licensed architect, MAA and a licensed civilengineer, IDA. He is a PhD Fellow at A&D and member of the Research Group for Sustainable Architectures and the Utzon Research Center. His research is entitled ‘Environmental Tectonics: Matter Based Architectural Computation’ investigating and creating environmental morphogenetic and adaptive design methods and models. Isak is the co-founder of the research based architectural practice AREA, located in Copenhagen.

Jacob Riiber is a PhD fellow at the Royal Danish Academy of Fine Arts, School of Architecture. His research investigates the possibility of a design practice based on the principles of self-organizing systems; collapsing conventional time and hierarchies of the design process into a single event of formation. Jacob has been a member of CITA since 2008 where he has worked on several research projects investigating intersections between architectural design, digital production and computer science. He has published several papers, exhibited and taught workshops, internationally as well as in Denmark.

Jan Henrik Hansen is an architect and founder of WHIST Architects in Zurich. He teaches and researches at the Chair for Architecture and Digital Fabrication with Professor Gramazio Kohler at ETH, Zurich and has considerable experience with high-end robotic fabrication strategies and infrastructure. In 2010 he founded Studio Jan Henrik Hansen to create an independent territory for his art projects and collaborations with architectural offices as an artist. this focuses on the transformation of music into space with a unique and patented digital technique he has been developing since 1999.
Johannes Rauff Greisen is Consultant at Danish Technological Institute, Concrete Centre working on an Industrial PhD project at Royal Academy of Fine Arts, School of Architecture, Center for Industrialised Architecture. The objectives of his research are the architectonic potentials in utilising industrial robots in concrete building. He addresses the architectural design process as a result of material-driven, vision-driven and fabrication-driven processes and claims that new CAM-tools are – just tools.

Contact:
www.dti.dk
www.cinark.dk

Jan Knippers studied civil engineering at the Technical University in Berlin. After several years in an international operating consultancy he founded Knippers Helbig Advanced Engineering in Stuttgart (2001) and New York (2008) with Thorsten Helbig. In parallel he is Professor and Head of the Institute for Building Structures and Structural Design (itke) at the faculty for architecture and urban design at the University of Stuttgart. In practice, research and teaching he focuses on highly efficient building structures and use of innovative building materials.

Contact:
j.knippers@itke.uni-stuttgart.de
www.itke.uni-stuttgart.de
www.khing.de

Jan Karlshøj has worked with the digital design, construction and operations throughout his professional career. He has worked and is working for major international consulting firms, and since his student days been in dialogue with the academic world. He has been instrumental in the establishment of IAI / Building Smart in Denmark, and has several positions in this international organization. He has participated in the planning, execution and implementation of “Det Digitale Byggeri (Digital Construction)” in Denmark, which was initiated by the Ministry of Industry and Construction.

Contact:
jak@byg.dtu.dk
www.byg.dtu.dk

Jan Knippers

Affiliation:
TU Stuttgart / Knippers Helbig Engineers / Stuttgart – New York

Contact:
j.knippers@itke.uni-stuttgart.de
www.itke.uni-stuttgart.de
www.khing.de

Johannes Beck is a graduate student at the Royal Danish Academy of Fine Arts, School of Architecture where he graduated with a Bachelor’s degree in Architecture in 2009. Johannes’ design work and research focuses on digital design strategies and how these link to fabrication technologies. In 2009/2010 Johannes worked at CITA, the Centre for Information Technology and Architecture, and in the last few years, he has assisted with many of CITA’s projects and exhibitions.

Contact:
johannesbeck.jb@gmail.com

Johan Bettum is a Professor of Architecture and the program director of the Städelschule Architecture Class. He has taught and lectured at the AA, UCLA, the Berlage Institute, Innsbruck University, the EPFL in Lausanne and Oslo School of Architecture. His main interests reside in the intersection between materials, geometry and advanced digital modelling. Bettum has a PhD in fibre-reinforced material systems. His practice, Archi|Globe, focuses on architecture within the context of research and experiments.

Contact:
jan.bettum@staedelschule.de
www.staedelschule.de/architecture

Johannes Rauff Greisen

Affiliation: Danish Technological Institute, Concrete Centre

Contact:
www.dti.dk
www.cinark.dk

Johannes Rauff Greisen, Architect MAA is Consultant at Danish Technological Institute, Concrete Centre working on an Industrial PhD project at Royal Academy of Fine Arts, School of Architecture, Center for Industrialised Architecture. The objectives of his research are the architectonic potentials in utilising industrial robots in concrete building. He addresses the architectural design process as a result of material-driven, vision-driven and fabrication-driven processes and claims that new CAM-tools are – just tools.

Contact:
www.dti.dk
www.cinark.dk

Joy Boutrup

Affiliation: Designschool Kolding

Contact:
jbo@dskd.dk
designskolenkolding.dk

Joy Boutrup

Textile engineer and expert in textile chemistry from Fachhochschule Niederrhein in Krefeld, Germany. She has worked in research at Textilforschungszentrum Nordwest in Krefeld and lectured in a tenure position at The Danish Design School. She is former head of Textile, Paper and Leather Conservation at the National Museum of Denmark. Currently she holds a part-time position as associate professor at Kolding School of Design combined with extensive lecturing activities all over the world.
Julian Lienhard earned his Diploma in Civil Engineering at the University of Stuttgart in 2007. He is currently writing his PhD on bending-active structures at the Institute of Building Structures and Structural Design (ITKE), supervised by Prof. Jan Knippers. He has been an active part of the academic environment at the ITKE since 2007 engaging in research and teaching. He is leading the German ministry funded research project “Pliable Surface Structures on the Basis of Bionic Principles” which was recently awarded the Techtextil Innovation Prize 2011.

Affiliation: Research Associate and PhD Candidate at the Institute of Building Structures and Structural Design (ITKE), University of Stuttgart, Germany.
Contact: j.lienhard@itke.uni-stuttgart.de
www.itke.uni-stuttgart.de/

Karen Marie Hasling combined a bachelor in textile technology with a master in design & innovation with the aim of enhancing the knowledge, awareness and use of textiles in markets outside apparel and interiors, e.g., in architecture. She has been researching in aesthetical and functional fiber composites, which emphasize the importance of using the textile component actively, creating a visual attractive form-flexible material. She works with materials in a broad sense and has a strong interest in ensuring that potentials of new materials and technologies are exploited with a holistic and sustainable mindset.

Contact: marie@tekstilingenior.dk

Karin Bech is an architect working with practice based research at the Centre for IT and Architecture in Copenhagen. She has been a collaborator on projects as Slow Furl, Thaw and ‘How would it be to live in a soft space’. In her work she explores the boundaries and relations between architecture and textile, asking how textile thinking and new digital design and production tools challenges architecture. Karin Bech is also the co-founder of the architectural office Byen Sover, working with urban ideas and conceptual design projects. Byen sover seeks to discuss the experience of the architectural landscape by proposing 1:1 interventions and conceptual designs in an urbane context.

Affiliation: Cand.Arch, Research Assistant CITA - Centre for Information Technology and Architecture Royal Academy of Fine Arts, School of Architecture
Contact: karin.bech@karch.dk

Marco Poletto

Affiliation: ecoLogicStudio and Architectural Association (AA)
Contact: research@ecologicstudio.com
www.ecoLogicStudio.com

ecoLogicStudio is an architectural and urban design studio co-founded in London by Claudia Pasquero and Marco Poletto. In the past few years the studio has built up an international reputation for its innovative work on ‘systemic’ design; ecoLogicStudio’s method is defined by the combination and integration of systemic thinking, bio-ecologic design, parametric design and rapid prototyping techniques. Completed projects include a public library, private villas, large facades and parametric roofs. Claudia and Marco are Unit Masters at the Architectural Association in London and Visiting Master tutors at IAAC in Barcelona.

Affiliation: ecoLogicStudio and Architectural Association (AA)
Contact: research@ecologicstudio.com
www.ecoLogicStudio.com

Karl Christiansen er arkitekt og lektor ved Arkitektskolen i Aarhus og tilknyttet Dansk Center for Integreret Design (CID)

Affiliation: Arkitektskolen Aarhus
Contact: karl.christiansen@aarch.dk

Mark Burry

Affiliation: sial – Spatial Information Laboratory – rmit, australia
Contact: mark.burry@rmit.edu.au
www.sial.rmit.edu.au

Professor Mark Burry is Director of RMIT’s Spatial Information Architecture Laboratory (SIAL), which has been established as a holistic transdisciplinary research environment dedicated to almost all aspects of contemporary spatial design activity. As consultant architect to the Temple Sagrada Família since 1979, he has been a key member within the local design team based on site in Barcelona, untangling Gaudí’s compositional strategies for his greatest work, especially those coming from his later years, the implications of which are only now becoming fully apparent as they are resolved for building purposes.
Markus Lampe has extensive experience with BIM, digital design and the operations method, which he gained over a period of 15 years. During this period he worked with renowned practices such as Diener & Diener Architekten and as a project leader with Juul & Frost arkitekter where he first introduced and lead the implementation of BIM tools. In 2009 Markus started working at the DTU where he was first involved in teaching BIM on the graduate course as well as advising external firms on using the modeling tool. In 2011 he extended his field of responsibility and started supporting the facility management organization of DTU, Campus Services.

Marta Malé-Alemany is a registered architect from Barcelona and the acting director of the Institute for Advanced Architecture of Catalonia (IAAC) in Barcelona since July 2011. Her academic research focuses on the conceptual and material opportunities that emerge from the use of digital design and fabrication technologies for the production of architecture. She directs her own professional studio in Barcelona and her research areas range from the analysis and concept development of parametric design proposals to the application of digital technologies for the materialization of complex forms.

As a member of the extended board of Blumer-Lehmann AG, Martin Antemann is responsible for the success and development of the company, especially in research, technical development and marketing. In the very unique designed and complex structures he is responsible for the customers satisfaction, quality and security of costs. Leading, project specific planning intern and extern, sourcing, production and installation, he can optimise all project steps. The benefit is his practical background in combination with his theoretical study.

Matthew is currently completing his Masters at the Kunstakademiet Arkitektskole in Copenhagen. He completed his Bachelors of Architecture at the Welsh School of Architecture in Cardiff, Wales and has just completed an internship at CITA.

Iain (Max) Maxwell is an Australian born registered Architect, design researcher and educator currently based in London. He holds a Masters in Architecture and Urbanism from the AA School London and is currently a tutor with the AA School’s Diploma Unit 16, London Metropolitan University’s Masters of Architecture and Digital Design Systems, and is an external advisor to the University of Canberra’s cross-disciplinary Masters of Digital Design. In 2006 he co-founded Supermanoeuvre, an award-winning design practice that has exhibited extensively in the USA, Asia, South America, Europe and Australia. In 2007 he was awarded the (Royal) Australian Institute of Architects Young Architect Prize.
Mette Ramsgard Thomsen is an architect working with digital technologies. Her research centres on the relationship between crafts and technology framed through “Digital Crafting” as way of questioning how computation, code and fabrication challenge architectural thinking and material practices. Her work is practice lead and through projects such as Thicket, Slow Furl, Strange Metabolisms and Vivisection she investigates the design and realisation of a behavioural space. Mette is Professor at the Royal Academy of Fine Arts, School of Architecture, where she heads the Centre for Information Technology and Architecture [CITA].

Michael Meredith is a partner in MOS, and an Associate Professor at Harvard University Graduate School of Design.

Prof. Michael U. Hensel [Dipl. Ing, Grad Dipl Des AA] is an architect, researcher, educator and writer. He is a founding member of OCEAN (1994) and founding Chair of the OCEAN Design Research Association (2008). He is also board member of BIONIS – The Biomimetics Network for Industrial Sustainability (since 2007). He is currently Professor for Research by Design at AHO – The Oslo School of Architecture and Design in Oslo, Norway. Previously he taught at the Architectural Association School of Architecture in London (1993 to 2009), where he developed the curriculum for and co-directed the Emergent Technologies and Design Program (2001 to 2009).

Morten Bandelow Winther is carpenter at Winther A/S Snedker- og Tømrermestre, in Fredriksværk.

Morten Bülow holds a Master’s degree in Architecture form The Royal Danish Academy of Fine Arts School of Architecture. He has worked as a digital fabrication consultant, and is currently pursuing a Postgraduate Master’s degree at the Institute for advanced architecture of Catalonia in Barcelona. His research is focused in the field between autonomous agent behavior and physical computing.

Neil Leach is a Visiting Professor at the University of Southern California. He has also taught at the Architectural Association, Columbia GSAPP, Cornell University, Dessau Institute of Architecture and SCI-Arc. He is the author, editor and translator of 19 books, including Rethinking Architecture, The Anaesthetics of Architecture, Designing for a Digital World, Digital Tectonics, Digital Cities and Camouflage, and is co-curator of the Machinic Processes exhibition at the Architecture Biennial Beijing 2010, and of the Swarm Intelligence exhibition in Gallery 5H, Shanghai, China.
Niels is an architect, currently working on his Ph.D. thesis on algorithmic design at Aarhus School of Architecture. Since he graduated in 1998 he has been working with both practice and teaching in Architecture. The research project is titled Tectonic Patterns and the goal is to develop methods for generating spatial formations through the use of algorithms and 3D modeling tools. The experiments are related to biological mechanisms such as growth, self-organization and evolution.

Oded Amir is a researcher at the Department of Mechanical Engineering, Technical University of Denmark. He is educated as a structural engineer from the Technion – Israel Institute of Technology and holds a PhD degree from the Technical University of Denmark. His research is in the field of topology optimization, where he wishes to promote applications in civil engineering. His current work is focused on studying and developing computational procedures for optimal design of reinforced concrete structures, under the framework of the project: “Topology Optimization for Reinforced Concrete Structures: Bridging Aesthetical Architecture and Efficient Engineering”.

Odilo Schoch is an Assistant Professor at the Centre for Information Technology and Architecture (CITA) at the Royal Academy of Fine Arts, School of Architecture in Copenhagen, Denmark. His current research elaborates approaches to handle the genesis of architecture in the early phases of a building by considering the demands of its whole lifecycle. This holistic approach links directly to both parametric design and sustainability. His research is based on professional experiences in offices such as Baumschlager-Eberle Architects, Gramazio Kohler Architects and Ove Arup and Partners.

Paul Nicholas holds a PhD in Architecture from RMIT University, Melbourne Australia, and joined the Center for Information Technology and Architecture (CITA) as an adjunct professor in 2011. Paul’s particular interest is in computational approaches that support interdependent design and thinking by establishing new and different links between architecture and other fields. Having previously worked at Arup Melbourne from 2005 and Edaw London from 2009, his current research explores the idea that composites, or designed materials, necessitate new relationships between material behaviour and digital representation. Paul co-founded the design practice mesne in 2005, and has exhibited in recent Beijing and Venice.
**Per Dombernowsky**

Affiliation: Arkiteksskole Aarhus

Contact: per.dombernowsky@aarch.dkk
www.fluxstructures.net

Per Dombernowsky holds a master of science in civil engineering from the Technical University of Denmark. In 1964-69 he was employed in consulting engineering companies in Copenhagen and Aarhus, and since 1967 he was employed at Aarhus School of Architecture. In 1969 he became an associate professor in building technology and structures. Per Dombernowsky has published several articles and papers at international conferences on computer based structural design and structural engineering. In association with the Danish Center of Integrated Design (1989-2002), he has conducted research in computer-aided shape- and topology optimisation, resulting in the publication ‘Optimeringsmanual’, 2003.

**Phil Ayres**

Affiliation: CITa Centre for IT and Architecture, Kunstakademiets Arkitektskole

Contact: phil.ayres@kadk.dk
www.cita.karch.dk

Phil Ayres is an architect, researcher and educator. He joined the ranks at CITa (Centre for Information Technology and Architecture, Royal Academy of Fine Arts, Copenhagen) in 2009 after a decade of teaching and research at the Bartlett School of Architecture in London, and completing his PhD in Denmark at the Aarhus School of Architecture. He has also been a partner of sixteen* (makers) since 1998. Phil’s explores the potentials that lie at the intersection between digital and material practice with a current focus on free-form metal inflation and developing supporting digital design environments.

**Reinhard Kropf**

Affiliation: Helen Hard Architects / Stavanger / Norway

Contact: rk@hha.no
www.hha.no

I lived in Graz, where I studied at the Technical University. In that period, I worked in various architectural offices before I moved to Oslo to study at AHO in the class of Sverre Fehn. Here I met Siv, I fell in love and we started Helen & Hard as students. Since then time went very fast. Siv and I always shared a passion for architecture, art and philosophy which we constantly try to foster and implement in our daily work. Besides working in the studio I teach at various universities including Kansas State University, AHO Oslo, ESA Paris or HUST Wuhan, China.

**Roland Snooks**

Affiliation: www.kokkugia.com

Roland snooks is a Design Director and a Founding Partner of kokkugia. He holds a masters in Advanced Architectural Design from Columbia University where he studied on a Fulbright scholarship and is a graduate of RMIT University (B.Arch). He teaches at the University of Pennsylvania, Columbia University and is the George Isaac Distinguished Fellow at the University of Southern California. Prior to founding kokkugia, he worked in the offices of Reiser + Umemoto, Ashton Raggatt McDougall and Minifie Nixon. His research is focused on emergent design methodologies involving agent-based techniques.

**Sean Ahlquist**

Affiliation: proces2
Institute for Computational Design at the University of Stuttgart

Contact: sean@proces2.com

Sean Ahlquist is the founder of Proces2, and is a Research Associate and PhD Candidate of the Institute for Computational Design at the University of Stuttgart. Ahlquist holds a Masters of Architecture degree from the Architectural Association in London – Emergent Design and Technologies Programme. His work spans both practice and theory. He has taught at UC Berkeley, California College of the Arts, and the AA. He has published, lectured and led workshops widely on computational design and fabrication techniques, including a forthcoming book entitled Computational Design Thinking, co-edited with Achim Menges.

**Sebastian Gmelin**

Contact: Sebastian.Gmelin@aarch.dk
www.gmelin.li

Sebastian Gmelin (Dipl. Ing. Architect, MAS Arch ETHZ) broadened his knowledge of digital tools and production methods during postgraduate Master studies at the chair of CAAD at the ETH in Zurich (2004- 2005). After, he worked as an associate architect for Foster + Partners in London and in 2009, co-founded the architectural studio “designyougo” in Berlin. He is currently a PhD student at Aarhus School of Architecture in Denmark, researching how specialised construction methods of complex geometries can lead to an optimised design workflow and a smooth transition to production.
Terri Peters is an architect and researcher from Canada currently researching sustainable building transformation as a PhD Fellow at the Aarhus School of Architecture in Denmark. Since 2003 she has written more than 200 published articles about architecture, technology and sustainability for international architectural publications such as Mark, Frame, Azure, Architects Journal and Architectural Design. She recently edited “Experimental Green Strategies: Redefining Ecological Design Research” John Wiley and Sons, 2011. Her role in Digital Crafting is as a reporter and correspondent documenting the workshops and symposia online. She is the editor of the extended catalogue.

Tobias Bonwetsch is senior researcher at ETH’s Laboratory for Architecture and Digital Fabrication chaired by Gramazio & Kohler. He completed his postgraduate studies at the ETH Zurich with a specialisation in Computer Aided Architectural Design. His research integrates the logic of digital fabrication into the architectural design process, with a special focus on additive production methods. In 2010, he co-founded ROB Technologies, to develop and implement robotic manufacturing processes at the interface of architectural design and the building industry. Currently he is completing his doctoral thesis at the ETH Zurich.

Thomas Juul Andersen is project leader for several research projects centered among the innovative use of concrete. Among these is Uniqua Concrete, which is a research into new methods for making unique concrete structures using robotic technology. Thomas Juul Andersen is one of the developers of the concept behind the High Technology Concrete Workshop at the Technological Institute.

Stig Anton Nielsen is an architect working with geometrical complex modelling and sensory environments. He is educated from the Royal Academy of Arts, School of Architecture Copenhagen and has been studying interactive environments in TUDelft Holland. He has been involved with local and international projects dealing with complex geometrical systems and he has been conducting workshops exploring architectural applications of interactive and active artifacts and environments. Stig Anton is currently employed as Research Assistant at the Centre for Information Technology and Architecture (CITA), located in the Royal Academy of Fine Arts, Copenhagen.

Sigurdur Omasson is an associate professor of civil engineering and researcher in the field of a finite element modelling with emphasis on wood mechanics and the design of timber structures. He has developed a simulation model that analyses stresses in solid timber and laminated timber products during variation in climatic conditions. This can be used for teaching purposes and can also be used in industry both as a supportive tool in the designing of wood products and as an instrument for helping to determine the appropriate dimensions for various construction elements.

Silvan Oesterle is an architect based in Zürich and faculty at the Professorship for Architecture and Digital Fabrication. He is the co-founder of ROK a design and research agency exploring the relationships between architecture, manufacturing and computation. He has given lectures at various schools, conferences and offices amongst which are the Architectural Association School of Architecture (London), UIC ESARQ School of Architecture (Barcelona), the Smart Geometry Conference (Munich) and UNStudio (Amsterdam). In 2007 Silvan earned a Master of Science in Architecture at ETH Zürich. He has worked as a designer for UNStudio (Amsterdam) and Riarch (New York).

Silvan Oesterle is an architect and research assistant at the Professorship for Architecture and Digital Fabrication. He is the co-founder of ROK a design and research agency exploring the relationships between architecture, manufacturing and computation. He has given lectures at various schools, conferences and offices amongst which are the Architectural Association School of Architecture (London), UIC ESARQ School of Architecture (Barcelona), the Smart Geometry Conference (Munich) and UNStudio (Amsterdam). In 2007 Silvan earned a Master of Science in Architecture at ETH Zürich. He has worked as a designer for UNStudio (Amsterdam) and Riarch (New York).

Tobias Bonwetsch is an associate professor of civil engineering and researcher in the field of a finite element modelling with emphasis on wood mechanics and the design of timber structures. He has developed a simulation model that analyses stresses in solid timber and laminated timber products during variation in climatic conditions. This can be used for teaching purposes and can also be used in industry both as a supportive tool in the designing of wood products and as an instrument for helping to determine the appropriate dimensions for various construction elements.

Thomas Juul Andersen is project leader for several research projects centered among the innovative use of concrete. Among these is Uniqua Concrete, which is a research into new methods for making unique concrete structures using robotic technology. Thomas Juul Andersen is one of the developers of the concept behind the High Technology Concrete Workshop at the Technological Institute.

Stig Anton Nielsen is an architect working with geometrical complex modelling and sensory environments. He is educated from the Royal Academy of Arts, School of Architecture Copenhagen and has been studying interactive environments in TUDelft Holland. He has been involved with local and international projects dealing with complex geometrical systems and he has been conducting workshops exploring architectural applications of interactive and active artifacts and environments. Stig Anton is currently employed as Research Assistant at the Centre for Information Technology and Architecture (CITA), located in the Royal Academy of Fine Arts, Copenhagen.

Sigurdur Omasson is an associate professor of civil engineering and researcher in the field of a finite element modelling with emphasis on wood mechanics and the design of timber structures. He has developed a simulation model that analyses stresses in solid timber and laminated timber products during variation in climatic conditions. This can be used for teaching purposes and can also be used in industry both as a supportive tool in the designing of wood products and as an instrument for helping to determine the appropriate dimensions for various construction elements.
For 10 years Tobias Wallisser was Associate Architect at UN Studio in Amsterdam, where he was responsible for a series of high profile projects including the Stuttgart Mercedes-Benz Museum. In 2007, he co-founded LAVA (laboratory for Visionary Architecture) with Chris Bosse and Alexander Rieck as an architecture think tank with offices in Stuttgart and Sydney. Lava operates as a network of specialists and projects include the Schumacher Tower, the green void installation and their winning competition entry for the center of the Co2-emission-free city Masdar.

Tobias Wallisser
Contact:
t.wallisser@l-a-v-a.net
www.l-a-v-a.net
www.architektur.abk-stuttgart.de

Tore Banke is a PhD Fellow at the Centre for Information Technology and Architecture (CITA) in Copenhagen Denmark. Tore’s research interest lies in the intersection between architectural and engineering design, focusing on the potential for low-resolution custom made design tools, for the architectural practice. His research is done in close collaboration with design teams at 3xn architects and light and energy consultants at Esbensen Engineers.

Tore Banke
Affiliation:
CITA . Royal Academy of Fine Arts,
School of Architecture
Contact:
tore.banke@karch.dk
www.cita.karch.dk/Menu/
PhD+Projects/Tore+Banke
www.parametri.dk

Tristan Simmonds is a specialist designer and engineer. His expertise lies in the design of complex geometrical and lightweight structures. He has been working as a specialist engineer for over 15 years and has developed a unique approach by combining digital computational techniques from the disciplines of mathematics, engineering and computer graphics to sculpt, design, engineer and fabricate complex and unusual structures.

In addition to architectural projects Tristan has long been involved in projects with artists including Anish Kapoor and Antony Gormley, carrying out research and realising large and ambitious projects.

Tristan Simmonds
Affiliation:
Tristansimmonds Studio / London
Contact:
tristan@tristansimmonds.com
www.tristansimmonds.com

Vibeke Riisberg
Affiliation:
Kolding School of Design
Contact:
vri@dskd.dk
www.designskolenkolding.dk

Vibeke holds a position as Associate Professor at Kolding School of Design. Based on her own work as a textile designer she is interested in exploring how aesthetic features such as: ornamentation, colours and textures can interact with digital media, function and sustainability. In 2006 Riisberg completed her PhD thesis: Design and Production of Printed Textiles – from analogue to digital processes. Current research includes various aspects of textile design and the influence of digital media on the profession and design education.

Vibeke Riisberg
PICTURE CREDITS

Page 1 Parawood, CITA (Copenhagen)
Page 3 Dermoid, CITA (Copenhagen), SIAL (Melbourne), Photo: Anders Ingvartsen
Page 7, 52 Fibrous Room, ecologicstudio, Claudia Pasquero and Marco Poletto (London)
Page 14, 20 Encoded Behaviour, CITA workshop with Department 8, Royal Academy of Fine Arts
School of Architecture (Copenhagen) photo: Martin Tamke, Paul Nicholas
Page 22 Composite Territories Installation, CITA 2012 (Copenhagen): Paul Nicholas and Martin Tamke,
photo: Anders Ingvartsen
Page 24 Listener, CITA (Denmark) and Technion (Tel Aviv), photo: Mette Ramsgard Thomsen
Page 25, 27 My Zeil Gallery, Massimiliano Fuksas with Knippers Helbig - Advanced Engineering,
(Stuttgart)
Page 26, 101 Shenzhen Airport, Massimiliano Fuksas with Knippers Helbig Advanced Engineering
(Stuttgart)
Page 28 Zip-Shape IV Installation, SchindlerSalmeron (Zuerich)
Page 36 Futuropolis, Daniel Liebeskind with Design2Production (Zuerich)
Page 38 Zip chair, SchindlerSalmeron (Zuerich)
Page 39 The Sequential Wall, Gramazio & Kohler, Architecture and Digital Fabrication, ETH
Zurich, Collaborators: Silvan Oesterle (project lead), Ralph Bärschi, Mike Lyrenmann,
Industry partner: Häring Timber Engineering, Isoflock, Students: Michael Bühler, David
Dalsass, Simon Filler, Milena Isler, Roman Kallweit, Morten Krog, Ellen Leuenberger,
Jonas Nauwelaertz de Agé, Jonathan Roider, Steffen Samberger, Chantal Thomet,
Rafael Venetz, Nik Werenfels
Page 40, 42, 44 many installation, Nach-Diplom-Studiengang (NAS), ETH (Zuerich)
Page 51, 53 Topology optimised concrete structure in Copenhagen, Unikabeton research project (Arhus)
Page 54, 56 Structures optimized with software, “TOSCA Structure” by FE-DESIGN GmbH,
illustrations: FE-DESIGN GmbH
Page 57 Topology optimised miniature manipulator, photo: Ole Sigmund
Acoustics, ETH Zürich, 2008 Elective Course, Gramazio & Kohler, Architecture and Digital Fabrication, ETH Zurich, Collaborators: Silvan Oesterle (project lead), Michael Lyrenmann, Ralph Bärtschi, Selected experts: Jürgen Strauss (Acoustics), Kurt Eggenschwiler, EMPA (Acoustics), Industry partner: Cellform AG, PU-Technik Meyer, Students: Christian Blasimann, Kathrin Hasler, Christoph Junk, Hannes Oswald, Barbara Zwicky

Page 59
The Perforated Wall, Gramazio & Kohler, Architecture and Digital Fabrication, ETH Zurich, in cooperation with: IFB ETH Zurich, Collaborators: Daniel Kobel (project lead), Ralph Bärtschi, Michael Lyrenmann, Selected experts: Patrick Stähli (IFB), August Morf (Holzco-Doka AG), Marcel Schneider (Holcim AG), Industry partner: Holcim AG, Holzco-Doka AG, Geberit AG, Students: Ladina Esslinger, Chris Keller, Willy Stähelin, Lorenz Weingart

Page 63
Pierre Huyghe Puppet Theater, mos-office, Michael Meredith and Hillary Sample (Princeton) photo: Florian Holzherr

Page 64
Hungerburgbahn, Zaha Hadid Architects (London) with Design2Production (Zuerich)

Page 65
Highly strung Field Forces, supermanoeuvre, illustration: Ian Maxwell

Page 66
Yeju Golf Resort, Shigeru Ban with Blumer Lehmann (Gossau), photo: Blumer Lehmann

Page 66
Villa Nurbs, Cloud9 (Barcelona)

Page 67
Project Dasher, Autodesk Research (Toronto)

Page 68
Masdar City Centre, LAVA (Stuttgart)

Page 69, 88, 95
Deep Surfaces, Proces2, Sean Ahlquist (Stuttgart), photos and illustrations: Sean Ahlquist

Page 69
Space Station, Anthony Gormley with Tristan Simmonds (London)

Page 70
Swarm Urbanism, Kokkugia (New York City, London)

Page 73, 77, 110
Lamella Flock, CITA (Copenhagen)

Page 80
Complex Phenomena Studio, Kokkugia (New York City, London)

Page 81
BabiYar Memorial, Kokkugia (New York City, London)

Page 85
Federal National Council competition, Abu Dhabi, Aedas (London)

Page 86
Pleckgate HS, Blackburn, Aedas (London)

Page 100
Research Pavilion, ICD & ITKE University Stuttgart, photo: Julian Lienhard

Page 102
Distortion II, CITA, Krydsrum (Copenhagen), Akkustikmiljø (Falkenberg), photo: Anders Ingvartsen

Page 105
Expo 2012 Pavilion Yeosu, soma Architects with Knippers Helbig - Advanced Engineering, (Stuttgart)

Page 106
Structural Oscillations, Gramazio & Kohler, Architecture and Digital Fabrication, ETH Zurich (Zuerich), In cooperation with: Reto Geiser, Client: BAK - Bundesamt für Kultur, Collaborators: Michael Knauss (project lead), Ralph Bärtschi, Tobias Bonwetsch, Nadine Jerchau, Michael Lyrenmann, Gregor Bieri, Michael Bühler, Hannes Oswald, Lukas Pauer, Model making: Lukas Pauer, Hannes Oswald, Sponsors: Keller Ziegeleien AG, Kuka Switzerland AG, Sika Switzerland AG

Page 108
ATOL Angers, AAVP & Antonio Virga Architecte, Gehry Technologies (Los Angeles, Paris)

Page 108
Ratatosk V&A London, Helen & Hard (Stavanger), photo: Pasi Aalto

Page 109
Vennesla Library, Helen & Hard (Stavanger), photo: Emile Ashley

All further images by Digital Crafting Network:
P. 5, 10, 31, 32, 33, 79, 91, 92, 93, 96, 97, 98 Claus Peder Pedersen
P. 8, 11, 48, 49 Johannes Rauff Greisen
P. 12 Asbjørn Søndergaard
P. 34, 53 Niels Martin Larsen
Cover, P. 36 Christoph Schindler
P. 74, 75, 76, 82 Sebastian Gmelin