Projects

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Modes of Design Development and Architectural Practice

Licentiate Thesis 2008

KTH School of Architecture and the Built Environment

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Projects Book

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Projects Introduction

The Projects book includes the design projects which have been the source of the conceptual development of the thesis. As projects, they can be regarded as assemblies of related research tracks, or lines of inquiry, where the design project is not only defining the boundaries of the research, but also providing context and affiliations to other tracks, informing and enrichening the exploration. The separation into the various research topics is not always clear, especially during the design development itself. This has been made more distinctive with the introduction of design loops, a part of a project presented as a separate design endeavor, or a later redevelopment of parts of a project. The design loops enable comparisons of concepts that reoccur in different projects.

The design projects presented in the thesis are all the result of team work. For the purposes of the PhD project *Prototype Development within Architecture*, and this licentiate thesis, the projects have been revisited. The original processes have been reframed in the design loops, with additional representational material for clarity, reflective thoughts over the process and in some cases complete redevelopments of certain parts of the design processes. The initial design development of the projects established many of the important issues later expanded on, and the participating members of the design teams are listed at the introduction of each project. I have been involved in all stages of design of the three main projects, *PARCEL*, *SplineGraft* and *Urbantoys v.2*, as a partner of the Krets research group. I have also been a tutor for the presented student projects, as part of my past teaching at the KTH School of Architecture.

A Reader's Guide

The *Projects* book relates to the *Contexts* book through references that establish links between the two. Usually bi-directional, they allow the reader to obtain a contextual understanding of a concept used in the Projects book, or a deeper understanding of the potential use of a term found in the Contexts book. The links may also be found between different parts of the two books. When referring from the Projects book to the Contexts book, the relevant phrase is set in bold, followed by an arrow and a page number ***like this*** ↓ [P.62] . When referring within the Projects book, the arrow is horizontal, indicating earlier or later parts of the text, ***like this*** ← [P.1] or ***this*** → [P.55]. A reference may also indicate multiple pages ***in this way*** ↓ [P.58 | P.63 | P.72]. These references could contextualize a discussion, clarify a concept or show potential outcomes of certain modes of operation, but most importantly, they allow for a fluid exchange between the discourses covered in the textbook and the projects presented as processes and results in the Projects book.

Design Projects, Design Loops and Prototypes

The ***design projects*** ↓ [P.12 | P.44] of the thesis primarily operate on an interior scale, but they also propose generic spatial systems with other potential implementations. In this way, they could evolve as an add-on to an existing environment, or be part of a design proposal of a larger scale. The potential multiple readings of the projects also allow another shift of scale; from the full scale prototype to the scale model. This could be exemplified with the ***PARCEL full scale prototype*** → [P.10], which frequently has been understood as a scale model of a façade cladding system. While such as an implementation would remove some of its performance, such as the interaction through recombination, others may become more important. The work presented in the ***P5 PARCEL Parametric Solution Space and Fabrication*** → [P.36] design loop in particular suggest formal variation that may be suitable for such applications. The way the projects allude to several scales and applications makes them valuable not only for the integrated research of their development processes, but also as suggestive proposals in themselves. The project joins the process and the resulting effect as primary concerns of the design driven research applied in this thesis. The methods and processes may be general in nature, but they achieve additional qualities in their project specific implementations, in which they are evaluated and made more accessible to other contexts. The design projects are revisited in what I have chosen to call *design loops*; relevant and coherent parts of the process of design development, production or performance of the proposed design. This separation into parts allows for studies of related concepts in different projects and more focused investigations of particular concerns. The design projects have been developed in different contexts, primarily within the Krets research group. The concepts explored reflect the motivations of several participants, while the conclusions are based on my personal research agenda. All design loops have been reformatted for integration into the thesis, and while the projects have been developed in collaboration, the conclusions presented in the loops are mine. In some cases, the entire design loop has been developed as a part of the this thesis, in which selected parts of a previous project have been further investigated or redefined.

The ***design prototypes*** ↓ [P.13 | P.22] can be seen as devices exploring different issues, slowly being formed into the design project which becomes a necessary framework for advanced studies. In the written part of the thesis, a similar approach has been at play, in the sense that certain conceptual tracks have been explored in parallel, later being formed into a coherent thesis. In both cases, the work has been initiated in an interest that is being explored informed and evaluated, rather than a thesis to be proved. A common denominator in the the incorporated design projects and the external references is the integration of technology into the design process as well as the resulting design proposal. This has been accomplished by collaboration with specialists in some instances, but also in my conscious effort to learn new digital tools beyond the average CAD system or animation package. Two particular software packages have played a significant role in the design techniques employed by the author during the past years. *Virtools*, currently owned and developed by Dassault Systemes, is meant for on-line real-time interactive 3D environments, and was used by Krets and Servo to develop the Urbantoys v.2 design system. *GenerativeComponents* (GC) is an associative and parametric modeling system integrated into the Microstation CAD package, developed by Bentley Systems with support from the Smart Geometry Group. GC was used in the development of the PARCEL and SplineGraft projects, as well as in the ***Informed Modularity and Architecture InFormation*** → [P.98] design studios at the KTH School of Architecture.

Key Concepts

A number of key concepts are being explored in the design projects and the presented design loops, as integral parts of the process, or as means of understanding final project performance. The concepts were in many cases identified and used in the initial design development, but a vital task for the re-framing process has been to make them more understandable. In this way, the concepts were important starting points when the projects were conceived and developed, and later refined further through the design development and reframing process. While the concepts may be used slightly differently in different projects, their generic qualities can be transposed between the presented projects, and hopefully to other contexts outside this thesis. ***Parametric models*** ↓ [P.16] are geometrical constructs in which specified parts can be manipulated through the change of a parameter or variable. Frequently, the parameters are also linked to each other, in hierarchal dependencies. In rare cases, these links may be bi-directional, indicating that parameters affect each other in both directions. A *design instance* is one specific derivative of a parametric model. The shifts between different design instances are often very smooth. A *design iteration* indicates a loop of design development, such as the generation of a design instance. It may also denote the development of a specific parametric model which can be the source for a great number of design instances, to be be further developed in later iterations (generating new instances). A ***design driver*** ↓ [P.16] is an important input to the design development. In a parametric model, it may be a specific parameter, but it may also be a more intuitive trait consciously looked for in the design iterations. A ***design constraint*** ↓ [P.16] defines the limits of the parametric models, defined in accordance with the context, or specific design inclinations. In some cases, the constraint becomes very important and operates as a driver. A ***design solution space*** ↓ [P.16] is the territory of possible solutions set by the design constraints and navigated by the design drivers.

Fabrication ↓ [P.17 | P.28] implies the production of something new, and potentially something fictional. For the purposes of this thesis, it is used as the act of exploring and defining new formal properties, through digital and physical manifestations. The means used are employed to achieve maximum effect in formal performance, but may not be applicable to rational serial or mass-customized production, even though these means and methods often coincide. ***Production*** ↓ [P.17 | P.30] research looks more into the issues of rational reproduction, to be implemented more or less with contemporary praxis as a constraint rather than a driver. There is no clear border between the two concepts, but rather a mediation. While principles for fabrication may be a driverwhen designing a formal variation, a later development can rely on production principles as constraints, looking for rational means to reproduce the particular variations on a larger scale.

Performance ↓ [P.16 | P.40 | P.44] indicates behavior of a project or prototype in operation. It is relevant both during the development of prototypes, as a direct design feedback, and as a source of important characteristics of the final proposal. ***Affect and effect*** ↓ [P.36 | P.60] are well used terms in the contemporary discussion. For the purposes of the presented design projects, they refer to the performance of the completed design project, in particular to formal expression and the user experience of different modes of interactions with the spatial proposals. Linked to issues of performance, the effect of a project may operate on several levels, for example giving rise to certain experiences, or conveying an understanding of underlying processes. The affect is regarded as a result of the effect, in essence a recognized reaction from the spectator or user.

Krets as a Research and Design Environment

Two of the main design projects within this thesis, PARCEL and SplineGraft, were developed within the *Krets* research group (www.krets.org). The third, Urbantoys v.2, is a *Servo* project (www.s-e-r-v-o.com), but Krets was commissioned for the system development of the responsive design browser at the core of the project. Krets was founded by partners Marcelyn Gow, Ulrika Karlsson, Pablo Miranda, Daniel Norell and Jonas Runberger in 2003, but had been taking shape in the years before in the local network of people interested in what became the main concerns of Krets; the social, visual and material effects of computation driven design and production technologies, and their incorporation in to architecture. The initial research agenda was largely a response to the convergence of architectural design, emerging electronic cultures, digitally enhanced fabrication strategies and ubiquitous computing. The work was driven by expertise and themes often found in neighboring disciplines such as new media and interaction design, but also by traditional architectural concerns such as modularity, surface articulation, graphics and infrastructure. Previous collective design work had primarily been part of Servo projects carried out in Stockholm, coordinated by Servo partners Marcelyn Gow and Ulrika Karlsson. The formation of Krets was also prompted by the simultaneous inception of *AKAD*, The Academy for Practice Based Research in Architecture and Design (www.akad.se), which provided a practice-based research context within AKAD's framework. AKAD is supported by the *Swedish Research Council*, which indirectly have supported many of the Krets activities.

The work of Krets is mostly known through the two projects PARCEL and SplineGraft, that have been published and exhibited extensively, most recently in the exhibition *Open House: Architecture and Technology for Intelligent Living*, organized by Vitra Design Museum and Art Center College of Design in Essen in 2006, and the *Ben van Berkel and the Theatre of Immanence* exhibition in Frankfurt in 2007. While these two projects represent the most visible part of the Krets' body of work, there are also other strands. The 2003 Urbantoys v.2 project focused on collaborative design environments and was developed using on-line game development software to create an on-screen, database-driven design environment for visitor interaction. A joint Servo / Krets workshop held at SIAL at RMIT University in Melbourne the same year furthered this research, and deployed the techniques in student environments. The public seminar *Prototypes for Performative Design*, held in 2003 at the KTH School of Architecture, looked into other design modes related to technology in art and architecture, featuring invited new media artists, architects and theorists. Another important area is algorithmically and parametrically generated and fabricated architecture. This research is ongoing and has so far been developed in workshops at The Royal Academy of Fine Arts in Copenhagen, at CECA at University of East London and in the Informed Modularity and Architecture InFormation design studios at the KTH School of Architecture in Stockholm. The *Gotland-Arena* project, a concept developed in collaboration with YAJ Architects, provided further opportunity to explore these issues, and is expected to commence with more implemented research into production methods and digital design systems linked to the building industry.

The collaborative work of Krets has always been based on overlapping individual interests and concerns within the field of experimental architecture, rather than the establishment or formation of a static organization. In this sense, the collective development of the design projects and participation in academic events and exhibitions, have depended on opportunities given by external forces as well as the initiatives and availability of each individual partner. All partners are also involved in other activities in the fields of practice, teaching and research within commercial firms as well as academic settings.

The collaborative design development of the projects that are an important part of this thesis, as well as the critical and projective environment that has been provided by the Krets network has been invaluable to the research that is presented in this thesis. Many of the core concepts explored in the projects, as well as in the Contexts book, are founded in the exchanges between the Krets partners. While the ideas behind the projects and other activities are shared among us, a majority of the discussions, speculations and conclusions of this thesis are however personal to me, and should not be regarded as the opinion of the Krets collective.

PARCEL
Design Project

With PARCEL, Krets suggests new ways of establishing relations between the material, audiovisual and digital techniques that are increasingly forming the environments around us. The project considers off-the-shelf technologies normally used in the packaging industry and consumer electronics as integral parts of an architectural design. Punched plastic sheets equipped with computational intelligence using microprocessors, printed circuits, and a variation of sensors, lighting and speakers, are folded into volumes. When combined, they form a wall-paneling system integrating information technology and infrastructure, as well as illumination and sound. The name PARCEL originates from the way that the singular units are partially enclosed to be able to house electronics, while not hiding them from view. Another connotation of the word parcel would be the act of distributing parts, to “parcel out”, relating to the modular aspects of the project. The assembly principles of PARCEL explored the potential for a striated and non-uniform expression, in the way that the different parts could be recombined.

The multifunctional quality of the graphic pattern as instruction for production suggests an ornamental transition from graphic to electronic to spatial infrastructure. PARCEL blurs the relationship between model and building, in this case the wall, and prototype and product, in this case the wall paneling system. Its capacity to continuously react and interact electronically with its environment, as well as invite the visitor to recombine and transfigure the system, also blurs the relation between architect and user.

Credits:
PARCEL is a Krets project developed by Krets partners Pablo Miranda, Daniel Norell and Jonas Runberger. The *P5 Parametric Solution Space and Fabrication* design loop have been developed by Jonas Runberger based on the previous work within Krets. The PARCEL development was supported by AKAD. The first PARCEL prototype received additional support from Stockholm Arts+Science 2004.

Presentations:
Stockholm Arts+Science 2004 at the Stockholm Concert hall. Design på gång public seminar at Kulturhuset Stockholm arranged by the Swedish Association of Architects, Stockholm (2005). Dorkbot-Sthlm event at CRAC, Stockholm (2005). AKAD at Lunds Konsthall (2006).

Special thanks to:
Erik Hökby, Mattias Rubin De Lima, Lars Åstrand, Vinkplast AB and Packningar och Plast AB.

Materials:
Punched and printed PVC sheets, conductive glue, paint and tape, PIC 12F629 Micro controllers, assorted electronic components, plastic membrane speakers, microphones, LED lights and paint NCS 2040-G10Y.

The PARCEL design loops:

P0 The *PARCEL Prototypes* design loop looks at the relation between the different prototypes developed during the different stages of the PARCEL design process.

P1 The *PARCEL Formal Development* design loop considers the material and formal properties of the folded PARCEL units, including detailing and production drivers.

P2 The *PARCEL Recombinatorial Potentials* design loop covers the effects of the user reconfiguration.

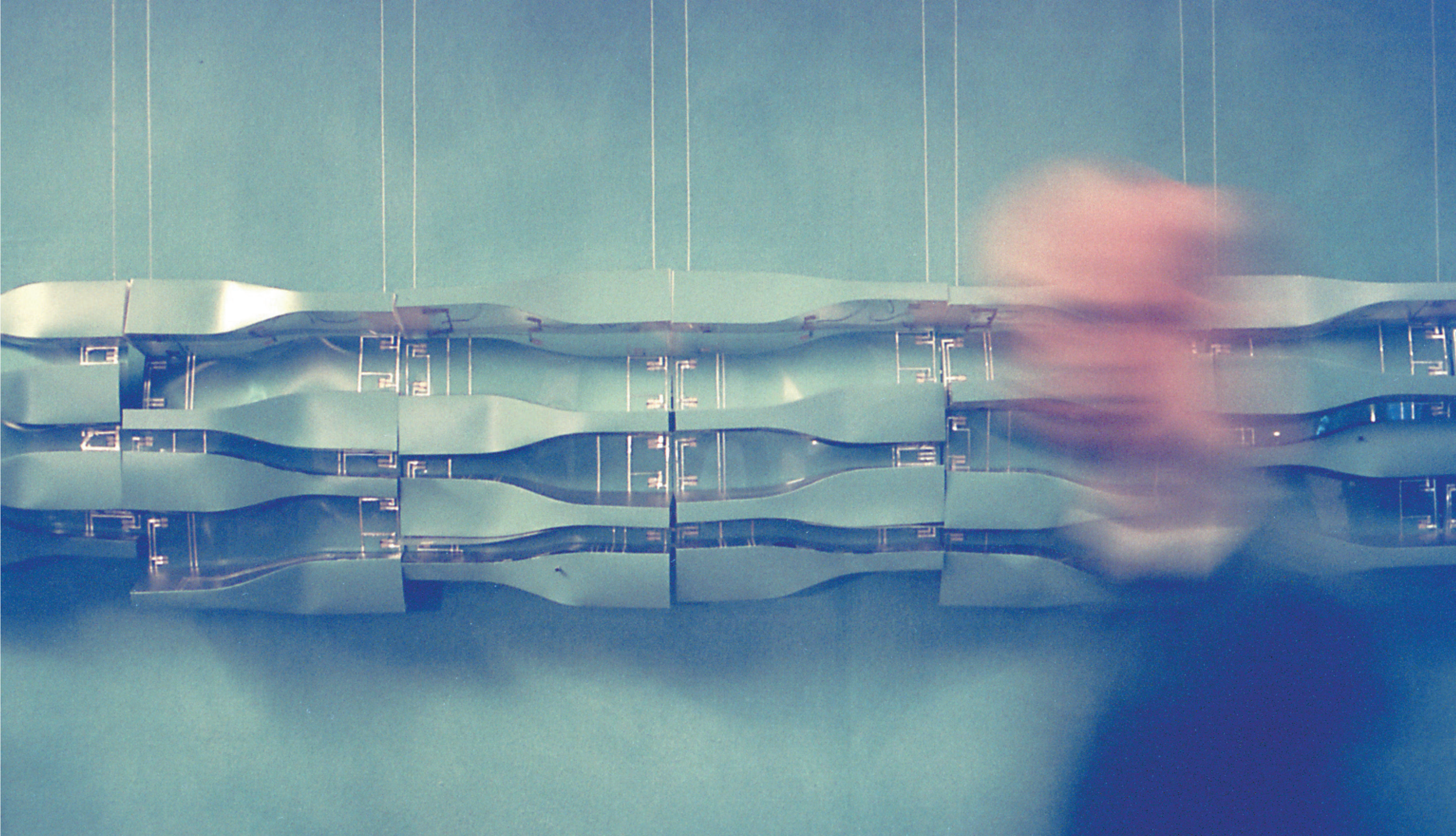
P3 The *PARCEL Ornamental Network* design loop considers the design of the integrated electronic network as enabler of the responsive behavior as well as its formal qualities as part of the PARCEL identity.

P4 The *PARCEL Production* design loop looks at production principles as drivers and constrains for development.

P5 The *PARCEL Parametric Solution Space and Fabrication* design loop looks into issues of design variation in a re-interpretation of the formal qualities of PARCEL. Linked to variable production principles, the fabrication part enables limited production by laser cutter through cutting patterns produced directly from the parametric model.

P6 The *PARCEL Performance* design loop considers the affect of the PARCEL formal characteristics, responsive properties and the user interaction through recombination.

The concept of ***the design project is further developed in the Contexts book*** ↓ [P.12 | P.44].

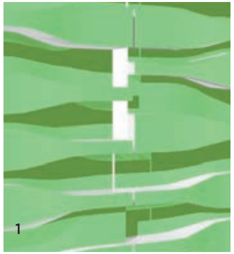


P0 PARCEL
Prototypes

The PARCEL project´s starting point was an interest in the potential of material cultures and fabrication principles of disposable articles and printed matter, off-the-shelf electronic components and programmed control systems. This was investigated through a series of prototypes that over time outlined a cohesive project of a certain scale, form and behaviour. The collections of prototypes allowed an innovative approach, rather than a start in a specification of a certain kind of product or spatial configuration. Each prototype included one or more components of the following: material and production capacities, modularity and patterning, program and performance, and tests through full-scale prototypes, presentations and documentation. The parallel development of the prototypes enabled a collaborative mode, in which certain aspects could be developed separately, to be assembled later in another generation of prototypes. In a way, this indicates that the development was PARCELed out in the individual prototypes, with a multitude of links between them.

1. The formal aspects were studied through series of *digital prototypes* that allowed precise control over the curvature of the foldlines, but depended on the parallel folded cardboard prototypes.
2. The *folded cardboard prototypes* explored the potential of the curved foldline, that provided structural integrity for each unit. These material studies also provided a direct understanding of the relation between the unfolded pattern and the folded *PARCEL* unit, the need for details and joints, and light studies.
3. The digital models also *prototyped the recombinatorial aspects*, in which the different types of PARCEL units can be combined in different ways, and also required coupling details developepd in the cardboard prototypes.
4. More detailed digital models explored the formal characteristics of the *electronic network in conjunction with the transparent qualities* of the frosted plastic used in the final PARCEL units through renderings.
5. The *connective behaviour and distribution of information* between the individual units were simulated in the open source programming environment *Processing*, enabling digital prototypes running on the similar algorithm as the final physical installation.
6. The *material properties of conductive ink, glue and tape* were tested and prototyped in conjunction with the material proporties of the folded plastic.
7. Potential *production technologies were partially prototyped* in the form of punching die cut tools derived directly from the unfolded digital originals. This is presented in the *p4 PARCEL production* design loop.
8. Design variations were explored in the *P5 PARCEL Parametric So lution Space and Fabrication* design loop, developed in a later study. This work explores the notion of solution space linked to fabrication aspects, in which each potential design has a corresponding pattern allowing the physical fabrication of that particular design instance.
9. The *PARCEL unit* is a physical prototype that collects the material aspects of the folded plastic sheets, the conductive paint, glue and tape and the programmed intelligence encapsulated in the integrated microprocessor.
10. The *PARCEL assembly* allows physical prototyping the emerging behaviour of the linked *PARCEL* units, in all performative aspects including the responsive behaviours, and the formal aesthetic characteristics. The assembly also achieves contextual qualities presented in the *p6 PARCEL Performance* design loop.
11. See 10.
12. The *PARCEL* innovation process is represented in the *PARCEL Development Flowchart*, which illustrates the way the at first separated *PARCEL* prototypes becomes related, and gradually forms the project.

The concept of ***prototypes is further developed in the Contexts book*** ↓ [P.13 | P.22 | P.26].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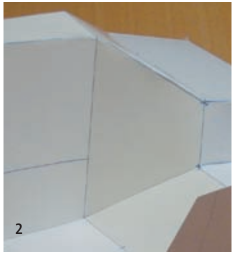
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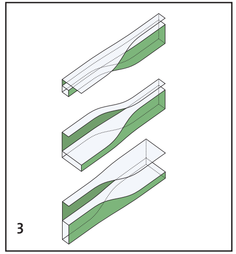
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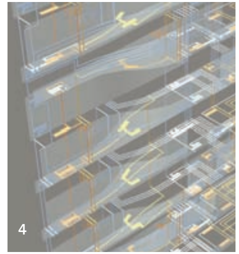
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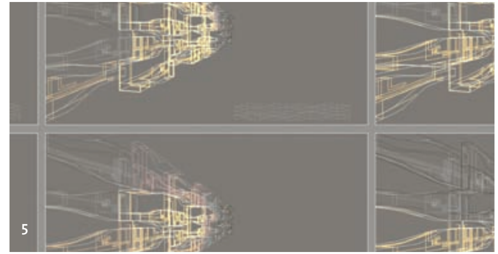
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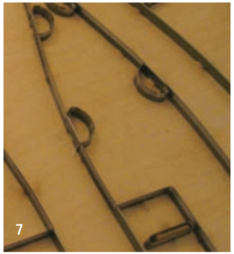
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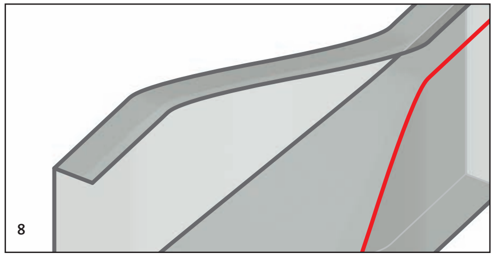
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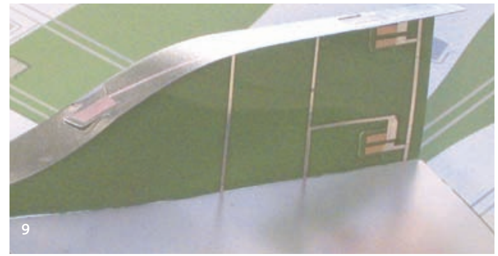
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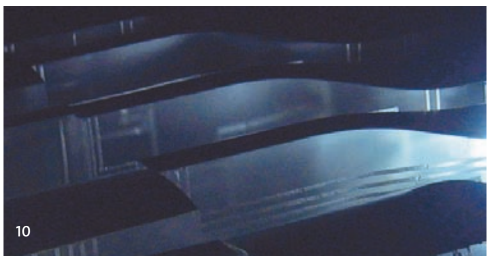
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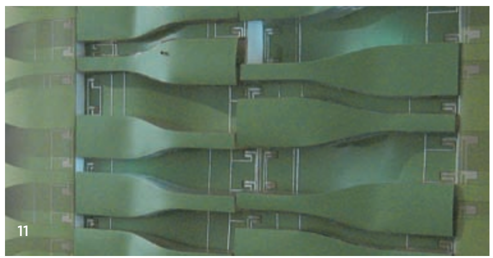
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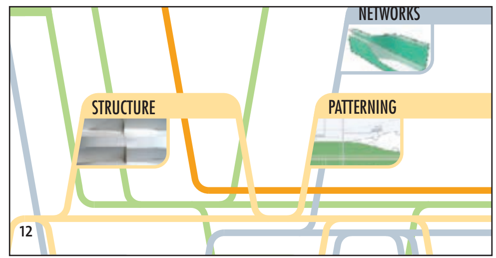

NETWORKS
STRUCTURE
PATTERNING
12

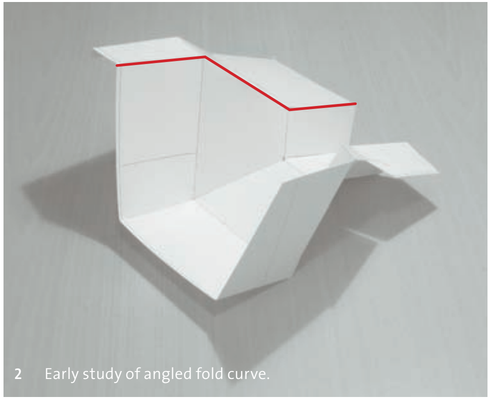
P1 PARCEL
Formal Development

The PARCEL project emanated from an interest in a number of specific phenomena and readily available technologies, which is reflected in the development of its formal properties. The material cultures and fabrication principles of disposable articles and printed matter suggest short-lived “throwaways” that are easily produced and distributed, and thus interesting in relation to a growing need for rethinking the use of plastics in architecture. Inexpensive, mass-produced electronics are increasingly infusing our environment with cellular intelligence. Computing power is becoming ubiquitous and readily available to such an extent that it takes on disposable qualities. Electronic circuits can today be printed onto almost any surface, making it possible to integrate microprocessors into products and environments ranging from household appliances to surveillance systems and clothing tags. They make up an invisible but nonetheless present and active part of our public and domestic spaces. Equally important, but less apparent, is the software driving these integrated devices. Their code plays a potentially important role in scripting the interaction between individual and environment, as well as the social interaction between individuals. Coding is becoming an act of design, where the scripting of behaviors is increasingly linked to the ambience of our environments. The cellular principles of the programmed intelligence suggested a similar approach to the physical components, in the development of interchangeable units of different performative qualities, but with common interfaces between them.

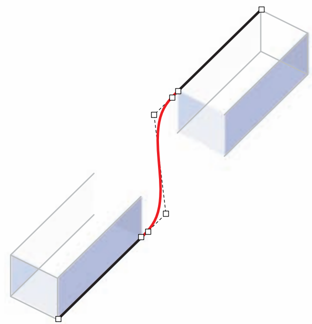
The operation of folding was the first design operation. While packaging products are typically folded in two directions (**image 1**), the first studies involved a fold line of a number of discrete angles (**image 2**), later smoothed into a curve. The insertion of this curve gave additional structural integrity by allowing the fold to resist forces in the two directions, snapping into its folded position from the unfolded sheet. A series of studies looked at the minimum curvature needed to achieve this structural principle, in relation to the aesthetic aspects of the folded surface. The studies integrated the material aspects of folding, such as the bending of a surface and how this is reflected in the shortening of its width in physical models (**image 3**), with a high control of curvatures and patterns developed through digital surface models. The digital models looked at the folded model, based on a curve blended between two straight lines off-set in two directions. The

1. In packaging structural integrity is achieved by adding the details to fold up a complete box with 6 sides.
2. A curved fold line, or a line with at least two different angles, achieves similar integrity without closing up the box.
3. Variations of curves were studied in physical models, exploring their material integrity and formal expression.
4. The initial curve for the fold line was developed by the blend between two offset and distanced straight lines. The curvature was controlled by adjusting control vertices.
5. Four repeated curves rotated 90° along their axes to each other and positioned at fixed distances from each other created the basis for box with curves in its folded sides, increasing stability while still being open to the sides.
6. This box became the basis for further development. Its folding principle allowed it to be fabricated from one continuous sheet of material.
7. See 6.

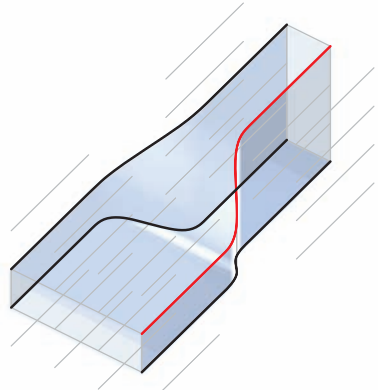
1 Example of packaging.



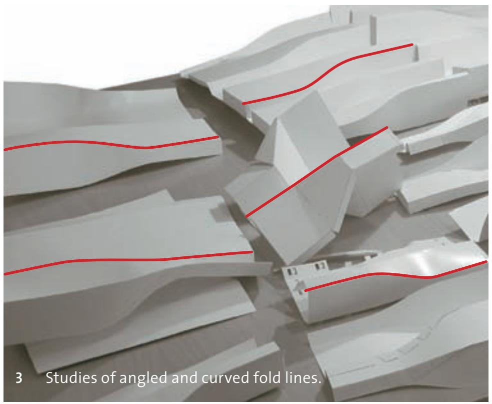
2 Early study of angled fold curve.



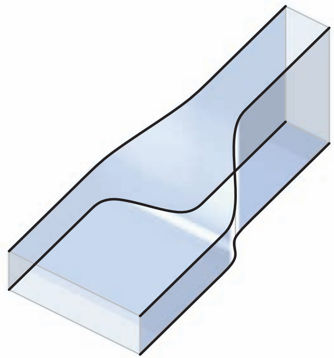
4 Digital generation of folding line curve as a blend.



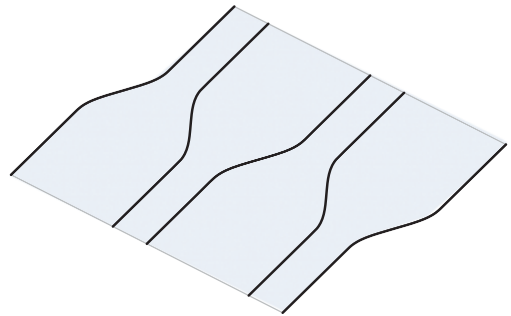
5 Fold line as one of four parts of the open box.



3 Studies of angled and curved fold lines.



6 Open box unit.

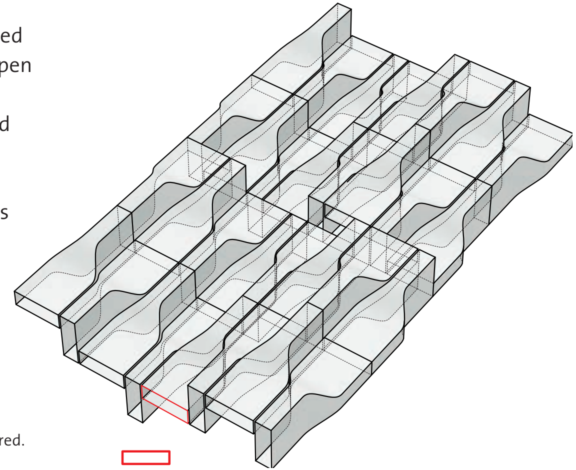


7 Unfolded sheet for open box unit.

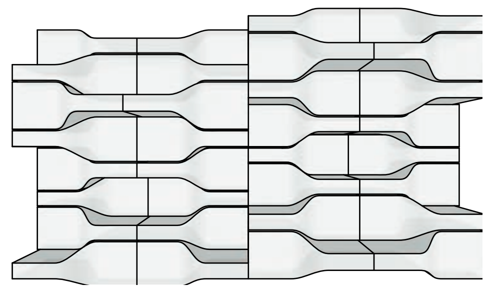
curvature could be controlled through the vertices of the B-spline curve. The initial fold line allows a sheet to be folded to a 90° angle, and with four fold lines a volume is achieved. In the folded volume, each fold line curve is rotated 90° to its neighbor (**image 5**). When unfolded to the flat sheet, each fold line is instead mirrored (**image 7**). This basic form can be defined as an open box, with both ends open, partially closed through the folds in one direction only.

The open box unit was put together as an assembly, forming a panel-like unit with differentiation in depth and a striated expression. While the repeated open box assembly achieved a reasonable high structural integrity, its identical building blocks made it quite repetitive. A parallel study looked at a folded surface assembly, with a surface that never encloses. While this could have been used to add more differentiation in the overall assembly, it was abandoned due to lack of structural integrity. The final development looked at a combination of the two, in which the open box principle brings structural integrity, and the folded surface potentially could add more variation to the assembly. These studies made clear that the curvature in each unit must be the same in order to make them fit to each other. The double connotations of folding a sheet into a volume or a parcel, and the act of distributing, or parceling out, material and behavior, suggested the project name, PARCEL. It is reflected in the open box that can hide away parts such as electronic control systems through being partly closed, and the appearance of componental principles in its physical form, as well as responsive principles. At the same time, the assemblies of PARCEL units suggested a wall paneling system, operating vertically in interior spaces, articulating walls and other planar surfaces into something that operates between surface and volume.

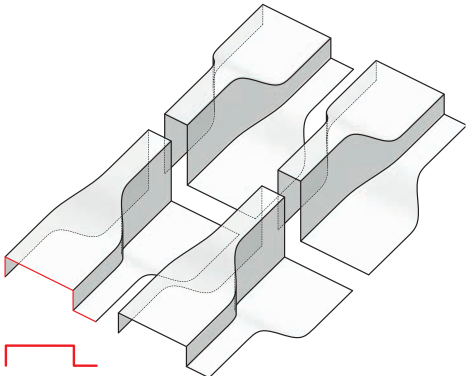
8. The open box assembly is based on identical but rotated semi-volumetric units with open ends. Profile indicated in red.
9. The assembly becomes highly repetitive, while a variation in depth is achieved.
10. The folded surface assembly does not contain any semi-volumetric parts. Profile indicated in red.
11. The final PARCEL assembly in its first version contains units that combine characteristics from the open box and folded surface assemblies. Profile indicated in red.
12. The unfolded PARCEL sheet may contain cuts that need additional detailing to attach. Profile indicated in red.
13. These cuts were tested in physical prototyping.
14. Physical prototyping of assembled PARCEL units.



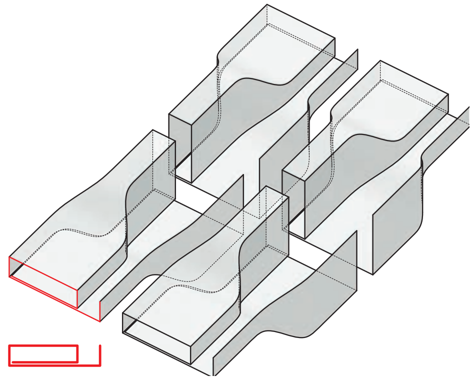
8 Open box assembly.



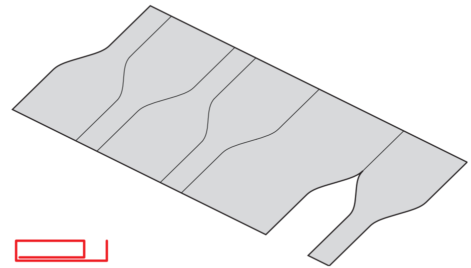
9 Open box assembly.



10 Folded surface assembly.

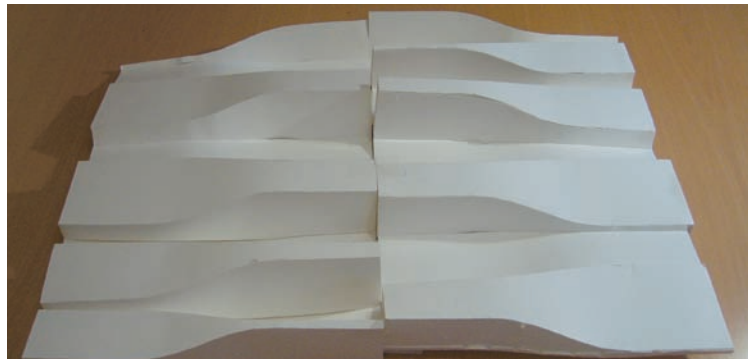


11 Open box and folded surface, the PARCEL assembly.



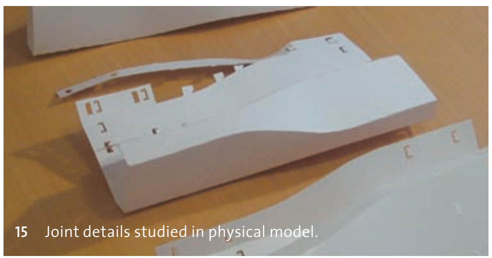
12 Unfolded sheet for PARCEL unit.

13 Physical prototyping of PARCEL units.



14 Physical prototyping of PARCEL assembly.

Based on the developed PARCEL unit, a set of three basic forms were derived, which could also be mirrored resulting in a total of six different PARCEL units. The selected PVC plastic is frosted on one side, while the other side retains the glossy qualities of untreated plastic. While the same ***production patterns for punching the plastic*** ↓ [P.30] could be used for each pair of mirrored units, the differentiation in surface treatment, as well as the different responsive aspects, required each if the six units to be treated differently. The development also included the design of detailing that allows each unit to be folded up, as well as connected to its neighbors. A simpler detail connects the two overlapping surfaces of the folded unit (**21c** and **21e**). The more advanced double joints for unit-to-unit attachment also allows the integration of conductors as shown in **image 15** as well as the ***P3 PARCEL Ornamental Network design loop*** ↓[P.28].

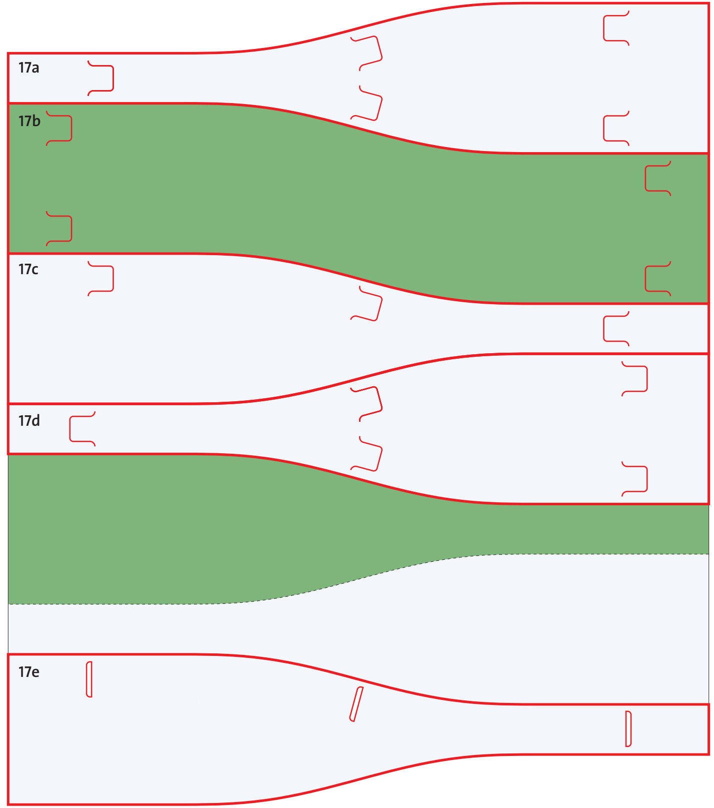

15 Joint details studied in physical model.

15. Joints studied in physical model.
16. Detail of unit to unit joint.
17. Joints of PARCEL B1:
17a. Joints for connecting to unit above.
17b. Joints to units on either side, by additional couplings.
17c. Joints for closing unit (connects to 17e).
17d. Joints for connecting to units below.
17e. Joints for closing unit (connects to 17c).

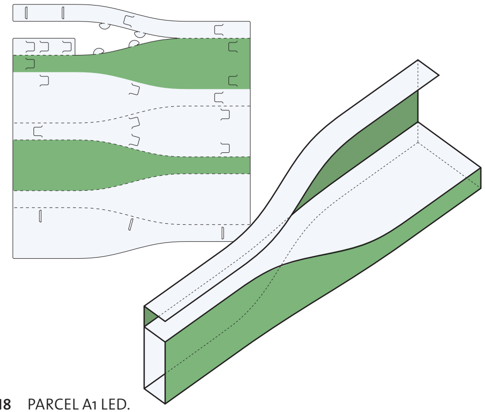
For the final PARCEL units three distinct forms were chosen, which when mirrored creates six different variants. The printed color and variations in performance makes the mirrored variants unique as well.

18. PARCEL A1 LED
19. PARCEL A2 SPEAKER
20. PARCEL B1 LED
21. PARCEL B2 LED
22. PARCEL C1 SPEAKER
23. PARCEL C2 MICROPHONE

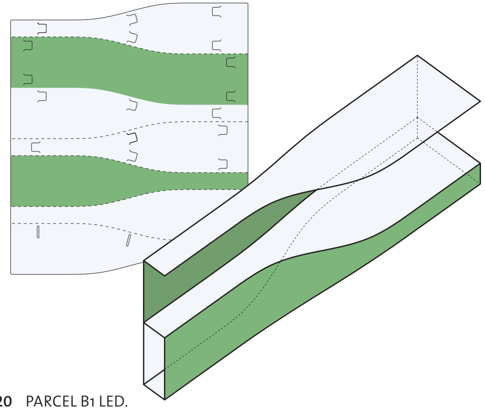

16 Joint detail.



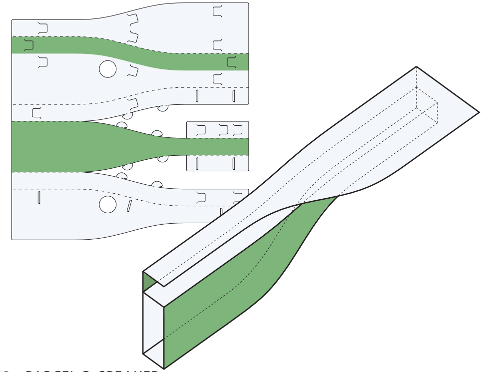
17 Joints of PARCEL B1.



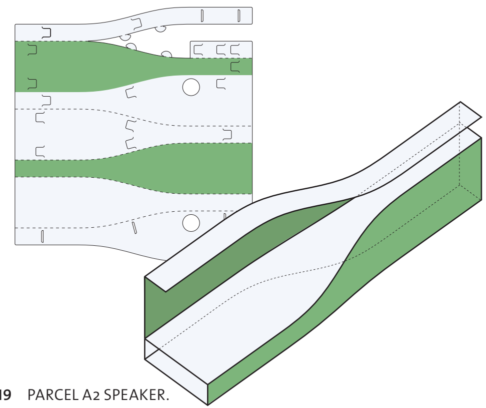
18 PARCEL A1 LED.



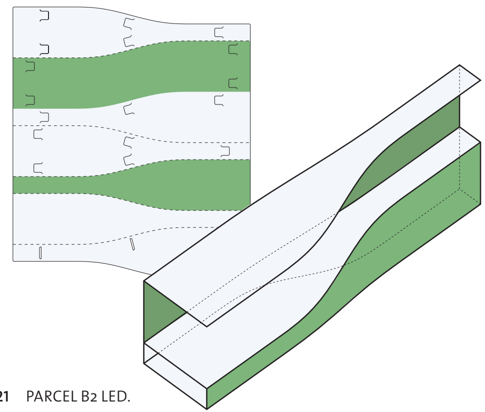
20 PARCEL B1 LED.



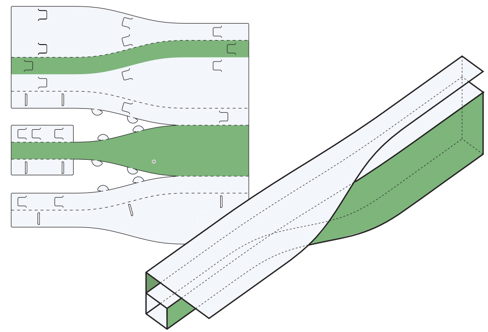
22 PARCEL C1 SPEAKER.



19 PARCEL A2 SPEAKER.



21 PARCEL B2 LED.

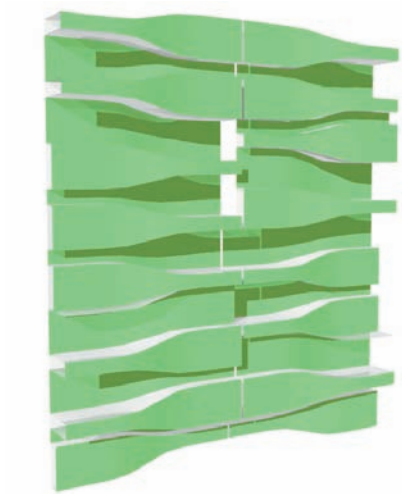


23 PARCEL C2 MICROPHONE.

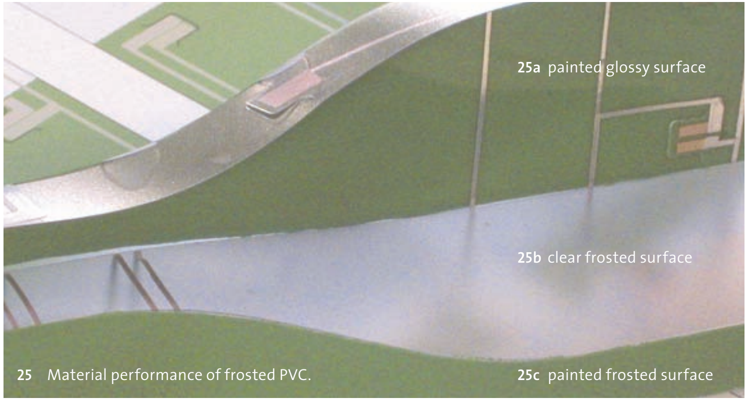
The invitation to present the project as part of the *Stockholm Arts+Science 2004* exhibition, offered the opportunity to continue the design development in a more contextual way. The exhibition took place in the Stockholm Concert Hall, designed by Swedish architect Ivar Tengbom and opened in 1926. A location in the foyer immediately outside of the main concert theatre on the second floor was chosen, providing a situation where visitors to events would relax and socialize between performances. The chosen wall also had a very particular green color, which suggested the opportunity for sampling this for use in the implemented project. The vertical positioning on a background of a particular color gave rise to the idea of emphasizing the shifts in depth of the PARCEL assembly, in which the vertical surfaces of each unit is printed in the selected color, while the horizontal surfaces make use of the translucent qualities of frosted PVC plastic. This entails that the interior of the folded volumes are even more hidden, unless a visitor approaches the volume up close. It also adds direction to the performance of the integrated LEDs, in that the outer painted surface acts as a shade, while the inner painted surface catches and reflects the light. The folding principle of the PARCEL unit makes one side of the original sheet visible on the outside of the open box part (**25b + 25c**, frosted PVC), while the inside of the single surface part between the boxes shows the other surface (**25a**, glossy PVC). The chosen paint is applied on the inner surface, which gives the paint a better finish. This also makes the vertical colored part of the box frosty green, and the inside surface glossy green. In this way, the material properties of the treated PVC are emphasized by the color. This effect is further explored in the ***ornamental patterning of the electronic network*** → [P.28].

The original sheet for each PARCEL unit was modeled after an A2 sheet, which allows the unfolded unit to follow format standards. The componental and cellular principles of the project allow it to be ***assembled in different configurations*** → [P.22] and extents, from a few units to a large scale wall. This suggests a play with the consumer aspects of architecture, related to the initial interests in consumer electronics and cheap manufacture, but also to classic designer items. A single PARCEL unit could become a separate item, to be purchased and collected individually, and assembled by the user later.

24. Digital model of wall panel assembly, showing the effect of shading from other light sources and color scheme with all directly visible vertical surfaces have color.
25. The material effects of the frosted and glossy sides of the PVC plastic. Paint has been applied from to the back side of the visible surfaces.
26. Early digital study of color scheme, in which the complete vertical backside of the unit is painted, rather than only the directly visible part.
27. Digital study of wall panel assembly on wall, emphasizing the shift from a flat surface to the deep form.
28. The selected location for the Stockholm Arts+Science 2004 presentation at the Stockholm Concert Hall.



24 Wall panel assembly in digital model.

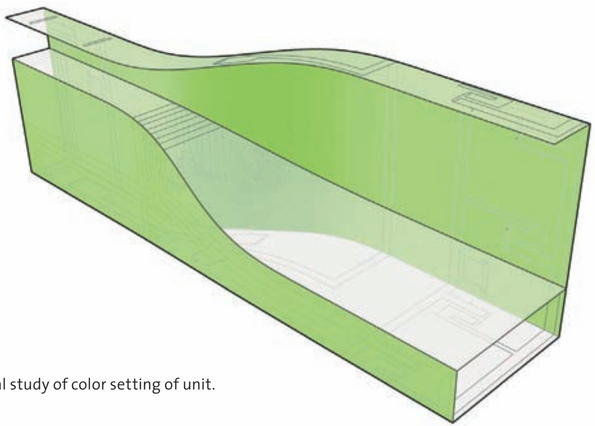


25a painted glossy surface

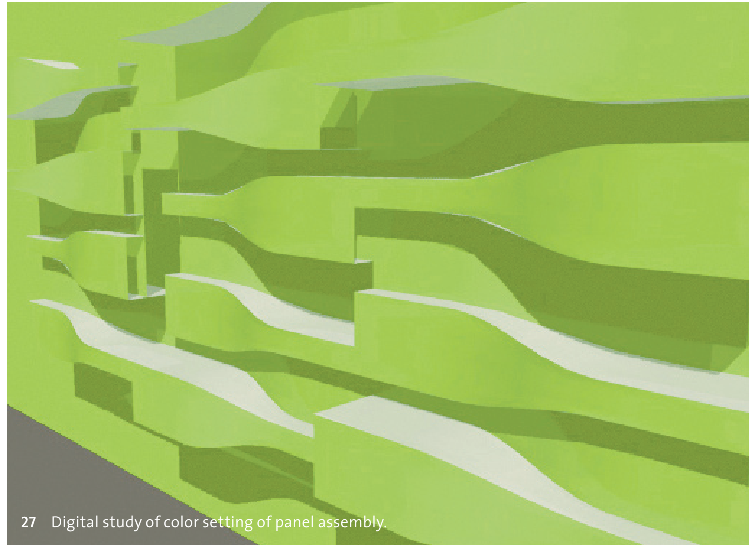
25b clear frosted surface

25c painted frosted surface

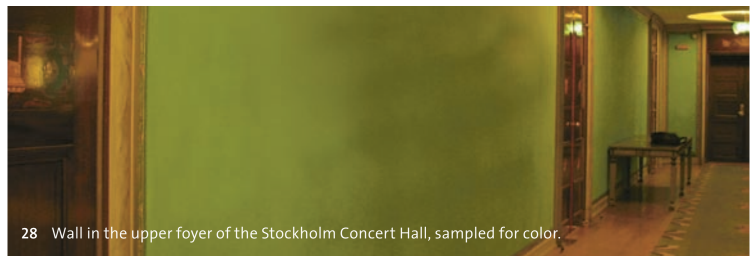
25 Material performance of frosted PVC.



26 Digital study of color setting of unit.



27 Digital study of color setting of panel assembly.



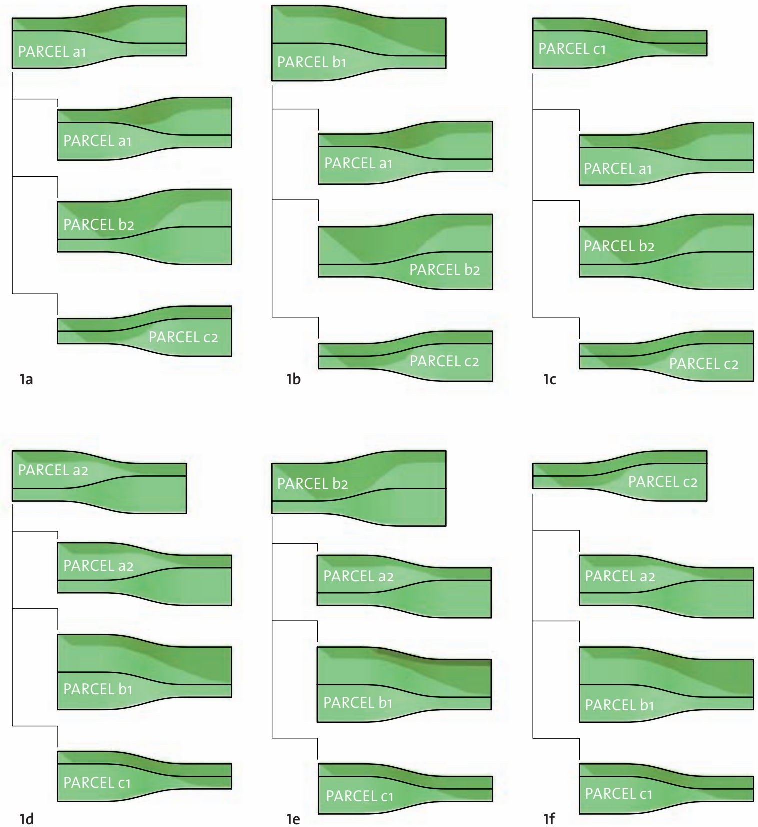
28 Wall in the upper foyer of the Stockholm Concert Hall, sampled for color.

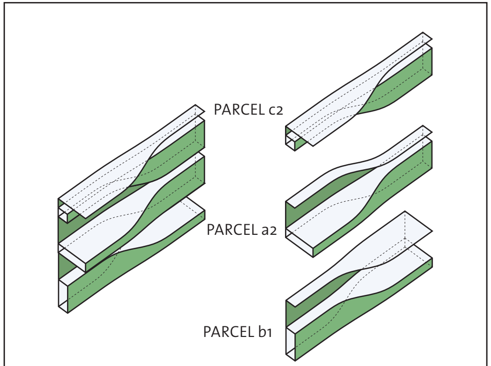
P2 PARCEL Recombinatorial Potentials

The top and bottom curve in elevation of each PARCEL unit is the result of the inflection of the folded surface. The bottom curvature directly reflects the direction of the ***integrated open box geometry*** ← [P.14]. The top curve is based on the type of folded surface integrated in the unit. In the complete series of six PARCEL units, each individual unit can be joined to one of three units on its bottom, as well as top side. This allows for a variation of the striated patterns of the panel assembly. While it is possible to create a quite uniform look, an equal use of all units will automatically result in differentiation. This differentiation is created by the left or right direction of the open box part, as well as the six unique variants of the folded surface part. While this configuration may be planned through modeling or sketching in advance, it is also possible for units to be fitted and re-fitted piece by piece. The form intuitively suggests how units fit, but the choices also reflect the overall patterns that gradually emerge. The open box part of each unit creates a tapering effect in one direction vertically, reversed

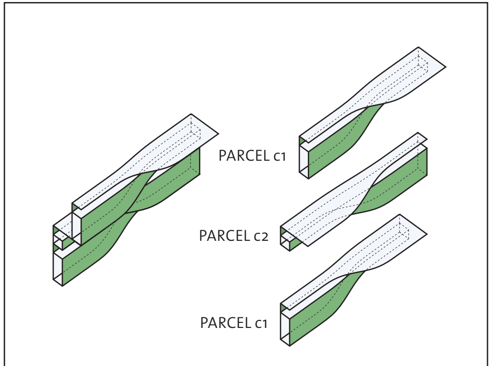
Image 1 shows possible PARCEL unit combinations, based on how one unit can fit below another one. PARCEL unit a1 can in this way be linked to another unit a1, to b2 or c2 at its bottom surface (**1a**). In reverse, unit a1 can be linked to a1, b1 and c1 at its top. PARCEL unit a2 can be linked to another unit a2, to b1 or c1 at its bottom surface (**1d**). In reverse, unit a2 can be linked to a2, b2 and c2 at its top. Units a1, b1 and c2 share the same bottom surface, and the same combinatorial set (**images 1a- 1c**), as do units a2, b2 and c2 (**images 1d-1f**). Units a1, b2 and c2 share the same top surfaces (**image 1a, 1e and 1f**), as do units a2, b1 and c1 (**images 1d, 1b** and **1c**).

Image 2 shows potential PARCEL configurations in sets of three, emphasizing the changes of vertical continuity/changes in panel depth. 2b and 2e has great difference in continuity across the panel, while 2a and 2f are fairly vertical.

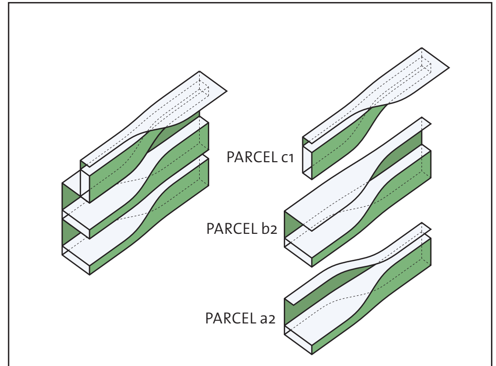




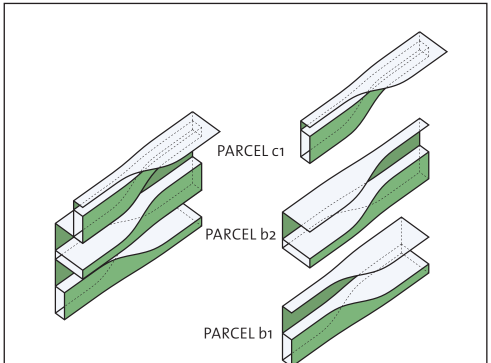
2a



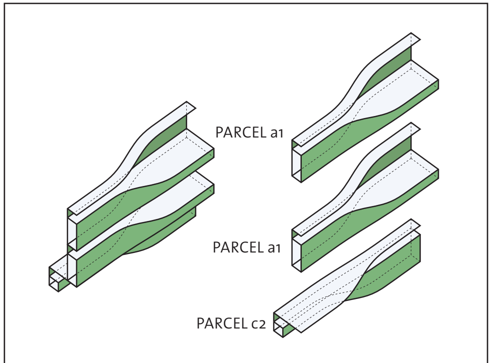
2b



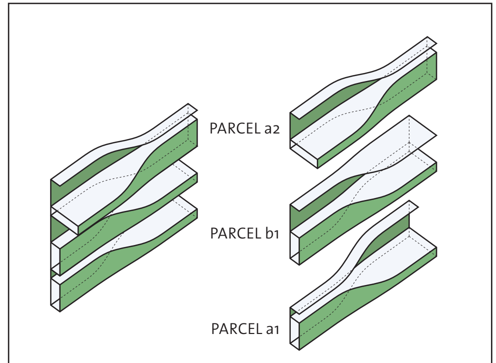
2c



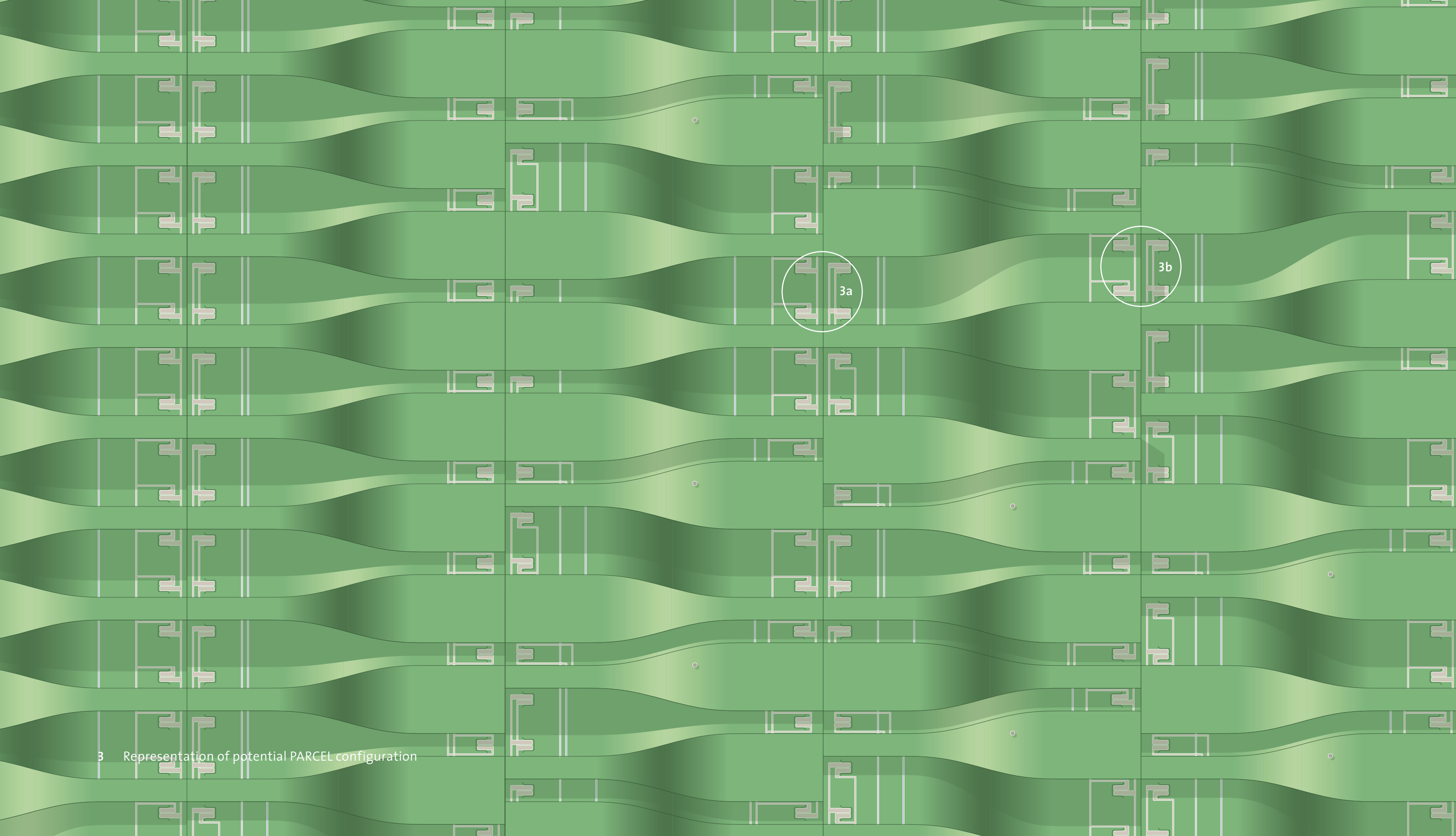
2d



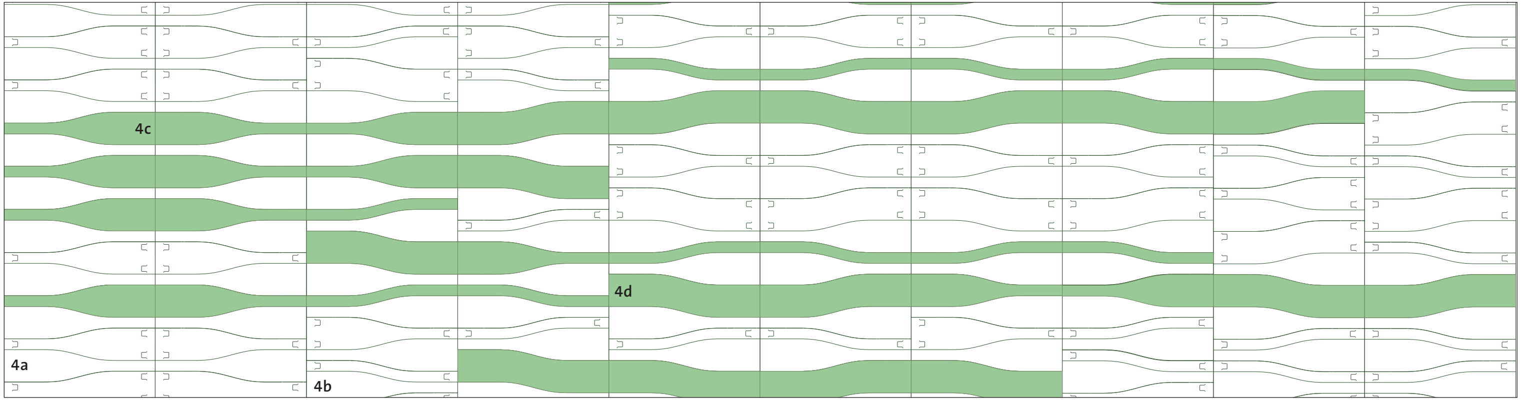
2e



2f



3 Representation of potential PARCEL configuration

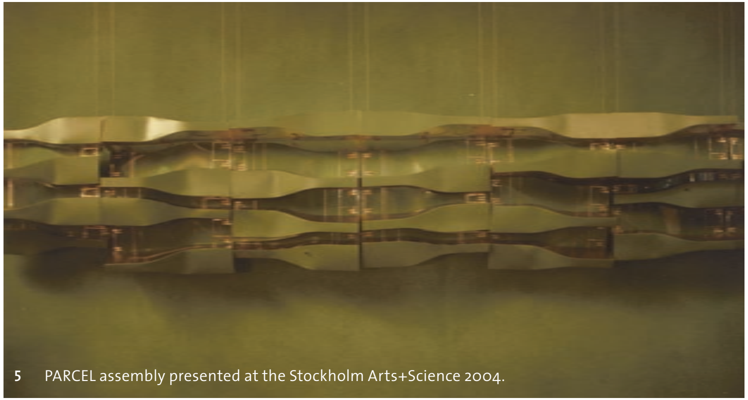


4 Potential PARCEL configurations of wall assembly, abstraction of image 3, continuous surfaces indicated.

horizontally, due to the ***vertical / horizontal configuration of each end*** ← [P.15]. The folded surface part of each unit has a shift in depth between each end, but primarily operates in elevation. These surfaces taper in units a1 / a2, and have parallel shifts in elevation in units b1 / b2 (wide surface) and c1 / c2 (narrow surface). The user configuration procedure would continuously get feedback from the developing patterns, which may include fold lines or complete surfaces continuing over a number of units, allowing the user to look for emerging patterns of choice. Differentiation in depth may show up in shifting shadows from external sources even if the forms are continuous in elevation (**image 3b**). The detailing for attachment also allows the conductive links to be broken and re-linked in operation, as a user moves a unit from one location to another. This adds changes in responsive behavior paralleling the re-configuration of the forms and patterns, due to the differences in electronic equipment in each unit.

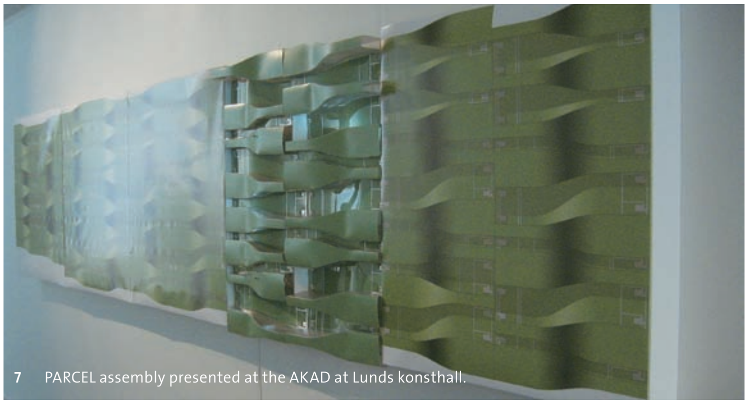
The user interaction with PARCEL hereby range from the selection and folding of units, ***initial configuration and re-configuration*** ↓ [P.18], as well as interaction with the ***PARCEL responsive behavior*** → [P.52].

Image 3 Potential PARCEL configurations of continuous wall assembly (previous spread). **3a** shows a continuous surface of the folded surface part of two units, with similar shadow. **3b** shows a continuous surface of the folded surface part of two units, with broken shadows indicating differences in depth. **Image 4** shows an abstracted view of the same set-up as in image 3, with highlighted continuous surfaces. **4a** shows two vertical rows of repetitive PARCEL patterns based on PARCEL units a1 (first row) and a2 (second row), with differentiation starting at **4b + 4c** shows continuous surfaces from the folded surfaces part spanning nine vertical assemblies. **4d** shows a break in continuous surfaces. **Image 5** shows the first PARCEL assembly presented at the Stockholm Arts+Science 2004 exhibition. In **image 6** Krets partner Daniel Norell reconfigures the assembly on-site. **Image 7 + 8** shows another more vertical assembly first presented at the AKAD at Lunds Konsthall exhibition, framed by printed representations suggesting a larger panel assembly.

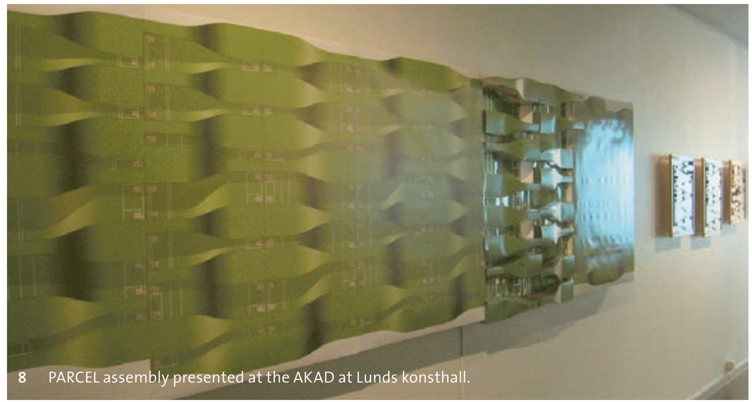


5 PARCEL assembly presented at the Stockholm Arts+Science 2004.

6 PARCEL recombination at the Stockholm Arts+Science 2004.



7 PARCEL assembly presented at the AKAD at Lunds konsthall.



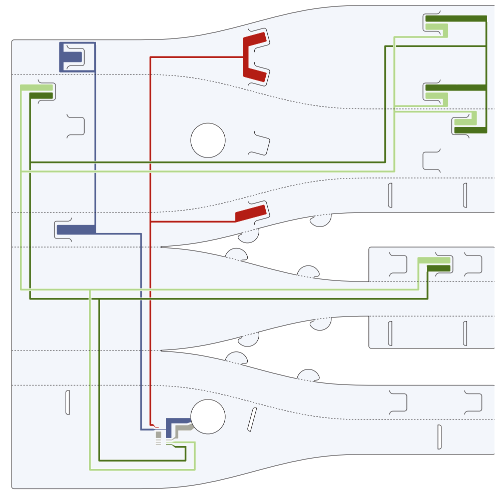
8 PARCEL assembly presented at the AKAD at Lunds konsthall.

P3 PARCEL Ornamental Network

The PARCEL assembly is powered through the conductive network of each contributing unit, which also provides the communicative network. The production patter is the template for the network of each unit. When folded the network becomes partly hidden inside the open box part, and in assemblies of units the printed color obstructs the view of the network in the open box parts, and becomes the backdrop in the folded surface part. The difference in effect is further enhanced by the glossy surface carrying the conductive lines, and the frosted surface covering parts of it, giving the characteristics of a ***frosted exterior and a glossy interior*** ← [P.20].

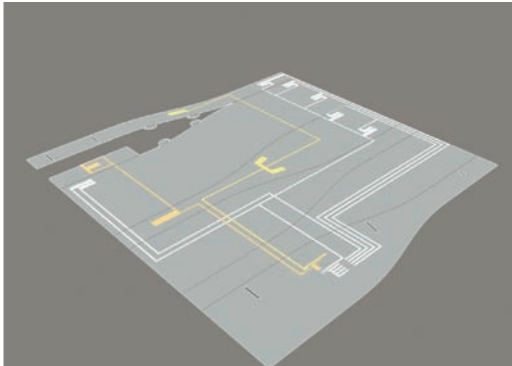
The network is also performative in a very literal sense, in that it enables the responsive aspects of PARCEL. It provides power and communication between each unit. The power is delivered vertically via two separate power lines, for positive and negative direct current. The asymmetrical location of the power lines in the left and middle of each unit is one reason for the need to make six different templates for the network, rather than the three needed for the ***die cut*** → [P.35]. Each joint provides space for one conductive pole. The communication network provides conductors for communication to and from the cellular microprocessors. Each connective joint provides two poles, one for each direction. The communicative network also operates horizontally between each unit, establishing a communicative meshwork of the PARCEL assembled panels. Both power and communication networks are linked at the joints, through the surfaces produced by conductive ink, automatically closing the circuit when a unit is attached to another. When power is provided to the top unit of each vertical stack it is directly transferred to all lower units, and the integrated microprocessors. The horizontal communication is established by additional components linking the double pole joints of each neighboring unit, and the remaining vertical joints provide communication in that direction.

The multifunctional quality of the graphic pattern as an instruction for production suggests a transition from graphic informational to electronic performative to spatial ornamental infrastructure. These aspects of PARCEL ***remediate*** ↓ [P.31] the relationship between model (its patterns) and building (the wall), and collections of prototypes and product (the wall paneling system), in its capacity to continuously react and interact electronically with its environment, as well as invite the visitor to

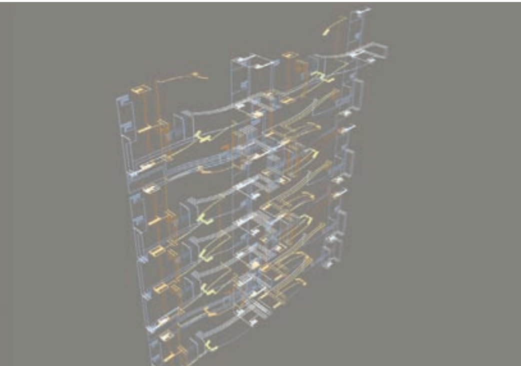


1 PARCEL conductive lines template.

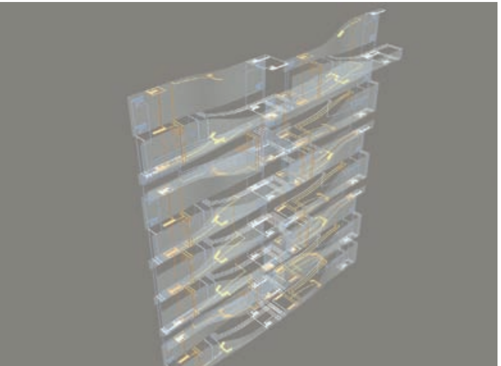
Image 1 shows the template for conductive lines PARCEL unit c1. Red indicates positive power supply, blue negative power supply, dark green communication going out, light green communication going in. The pattern in **image 2** is initially laid out on the unfolded unit based on its functional requirements, which when folded in the single unit is less readable, and when joined in the assembly of units reads as highly decorative (**image 3+4**). The partly obstructed view of the network is presented in **image 5**.



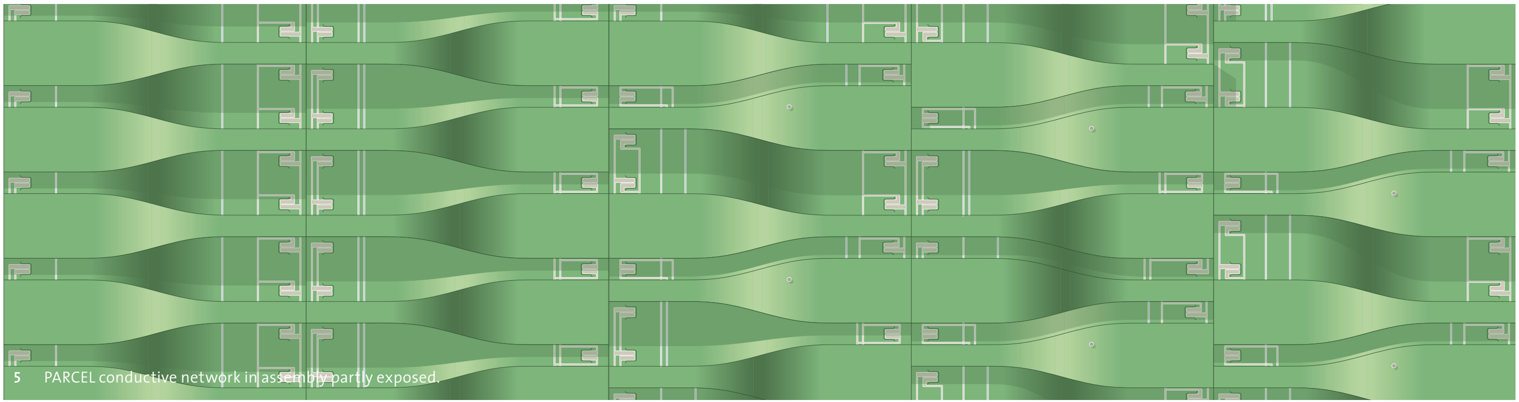
2 PARCEL conductive network pattern on unfolded unit.



3 PARCEL conductive network in assembly only.



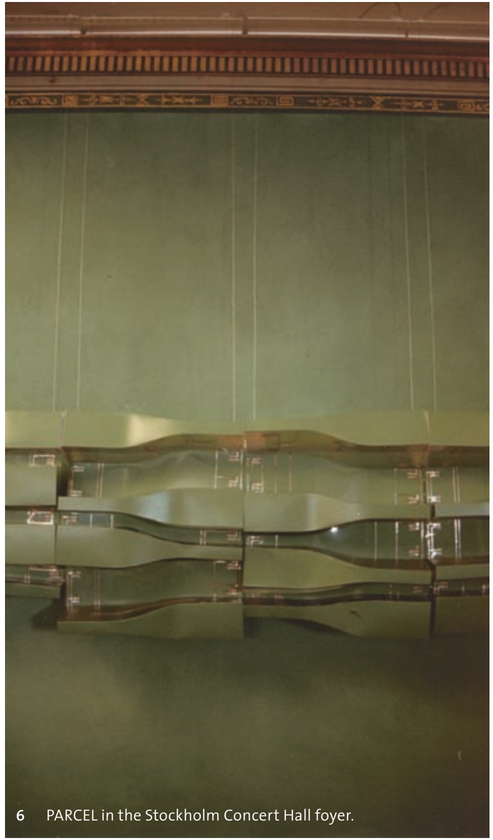
4 PARCEL conductive network in assembly with units.



5 PARCEL conductive network in assembly partly exposed.

collect, assemble and reconfigure the system. Today's individual and collective spaces are saturated with information networks and control mechanisms, ranging from automatic doors, to information displays and surveillance systems. The social protocols of such densely electronic material are strongly dependent on the presence they have in a space. By appropriating these systems into the architectural design process, they become part of the overall design agenda, and can be articulated accordingly. An extension may lead to new models for social exchange in space, which can be compared to the spread of Internet communities over the past decade. In the presentation of PARCEL at the *Stockholm Arts+Science 2004*, the ornamental network also interacted with the historic ornamental effects at play in the saturated interior environments of Tengbom's Concert Hall.

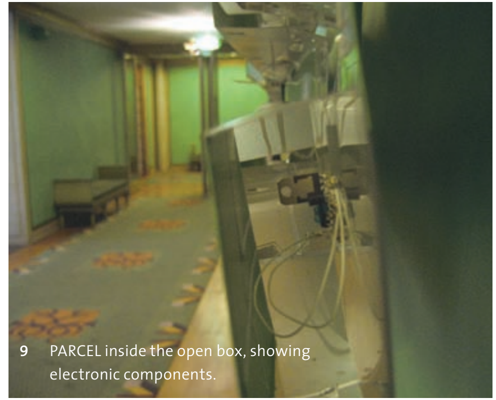
Image 6+7 shows PARCEL in location in the upper foyer of the Stockholm Concert Hall, where the silver of ornamental network can be related to the golden ornaments of the wall. **Image 8** shows more of the foyer and the presentation of production templates. **Image 9** shows a view of components, another level of ornament. **Image 10** shows the ornamental qualities enhanced by the internal LED.



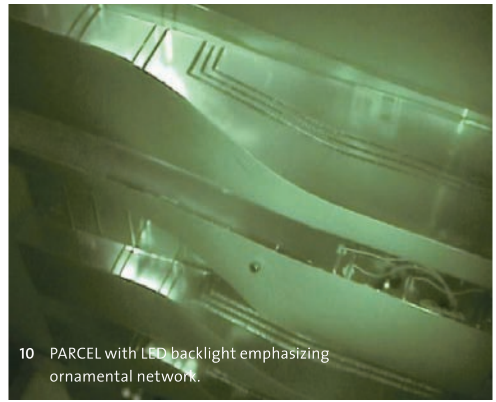
6 PARCEL in the Stockholm Concert Hall foyer.

7 PARCEL and the ornaments of the Stockholm Concert Hall .

8 PARCEL and the ornaments of the Stockholm Concert Hall interiors.



9 PARCEL inside the open box, showing electronic components.

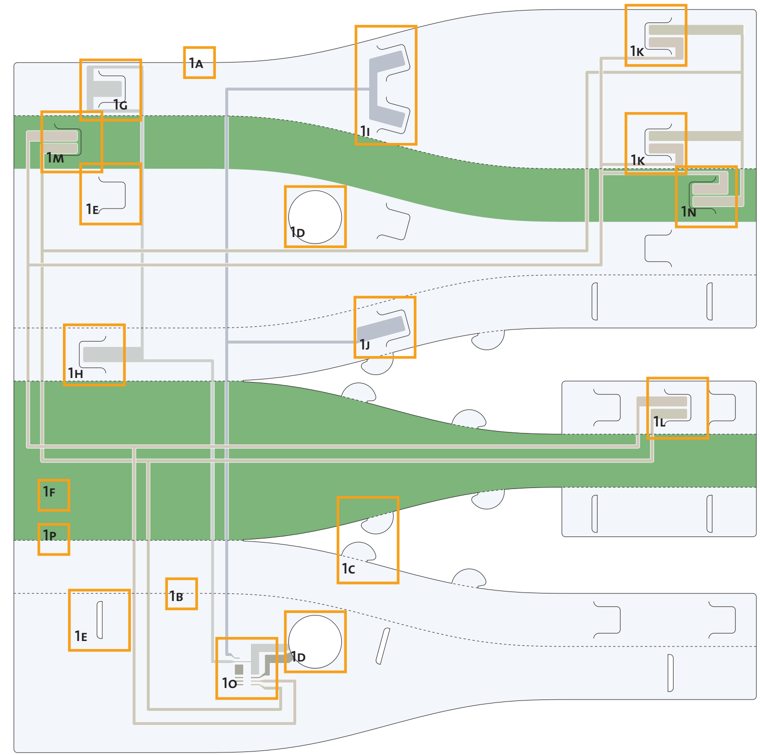


10 PARCEL with LED backlight emphasizing ornamental network.

P4 PARCEL Production

The original interest in packaging design also suggested the use of similar production technologies, including printing color, as well as printed circuits and die cut punching and folding. The conditions for the PARCEL development allowed for the full exploration of one of these principles, while the remaining were investigated in parts. The preparation for production testing was done in scale 1:1, with templates for all integrated systems integrated in one single drawing. In this way, the formal principles of the PARCEL prototypes were imported from printed matter and disposable articles, transferring their qualities to an interior scale. The drawing is ***remediated* ↓** [P.31] into the spatial system through the parallel production processes, the folding operation that finally shapes the PARCEL units and the assembly of units into the wall panel system. The specific functional parts of the different systems become fully integrated into the details of the production drawing. Many of the cut lines for the assembly details are closely related to print templates for the conductive ink, for the vertical power transmissions (as in **image 1g**), as well as unit-to-unit communication (as in **image 1k**). In some cases, the score lines

Image 1 shows the complete production information for PARCEL unit c1. **1a** Cut line for the die cut tool. **1b** Score line for the die cut tool. **1c** Cut line for unit assembly details. **1d** Cut line for speaker attachments. **1e** Cut line for unit assembly details. **1f** Template for color printing. **1g** Cut line and template for conductive ink; upper power supply, negative pole. **1h** Cut line and template for conductive ink; lower power supply, negative pole. **1i** Cut line and template for conductive ink; upper power supply, positive pole. **1j** Cut line and template for conductive ink; lower power supply, positive pole. **1k** Cut line and template for conductive ink; upper communication link, double poles. **1l** Cut line and template for conductive ink; lower communication link, double poles. **1m** Cut line and template for conductive ink; left communication link, double poles. **1n** Cut line and template for conductive ink; right communication link, double poles. **1o** template for conductive ink; electronic component base. **1p** Score line/printed color boundary.



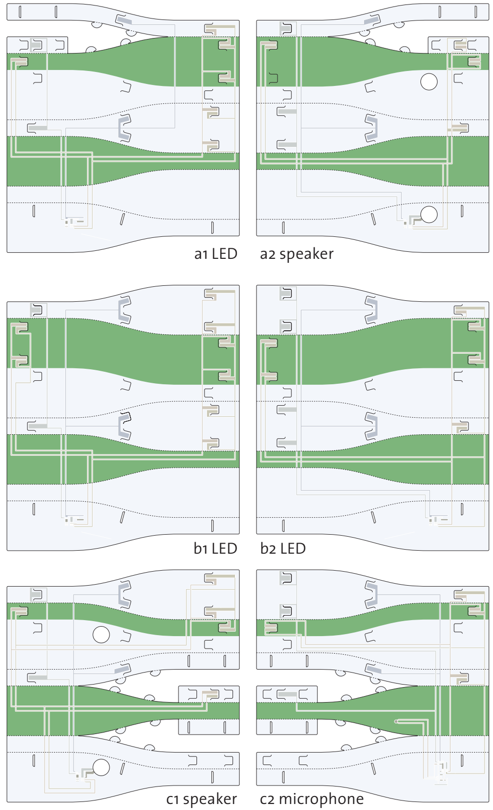
1 Combined production information for PARCEL unit C1.

Image 2+3 shows other examples of steel rule dies set in laser cut plywood. **Image 4** includes the three die cut tools used for cutting and scoring the six PARCEL units. **Image 5** includes the complete patterns for all six units. **Image 6** shows the complete pattern for PARCEL unit c1, in relation to the produced unfolded unit in **image 7**.

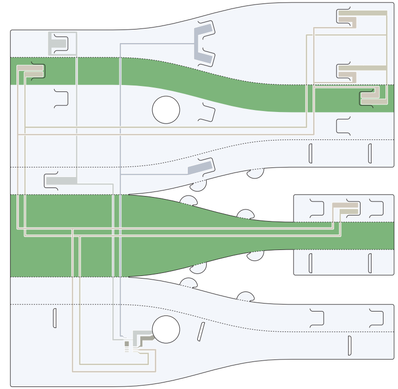
2 Steel rule die.

3 Steel rule die.

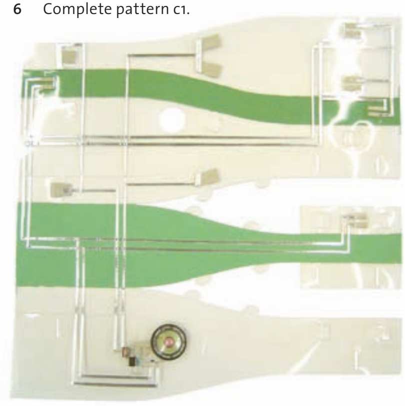
4 Die cut tools.



5 Complete patterns all units.



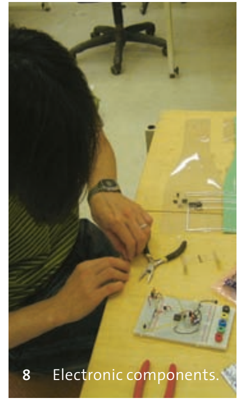
6 Complete pattern c1.



7 Completed unfolded unit c1.

are identical to the boundaries for the color print (**image 1p**). The cutting and scoring production aspects were fully deployed. The template for the die cut tool that integrates these two aspects was extracted from the integrated production drawing. While the six types of PARCEL units require individual drawings due to the electronic network and material aspects of the PVC plastic in conjunction with the printed color, the die cut tools could be reduced to three, using reversed plastic sheets (shifting the frosted side) for the remaining three. The die is constructed out of a flat base substrate made out of high-grade and high-density plywood. The production template is used for laser cutting slits in which hardened steel cutting and scoring steel rules or blades are inserted. The blades are also formed directly from the digital template, allowing a very exact forming of radii for detailing. In the die blades, the cut and score parts differ only in sharpness. The score lines can be placed on either the inside or outside of the folded surface, which enables the flipping of the material to make the mirrored versions (making sure the inside is always the glossy side of the PVC). The die cut tool is placed in a die cutting press providing 20 tons of pressure. For production purposes, the die cut tool also requires ejection rubbers, which compress during the press operation, and expand after easing the extraction of the material from the tool. The remaining production techniques, including printing conductive circuits and colored features and attaching electronic components, were forced to be simulated manually. Painting the sheets from the backside provided a good finish despite the manual production. Conductive ink was applied with masks for the details in the joints and the basis for electronic components. These locations were then linked using conductive tape.

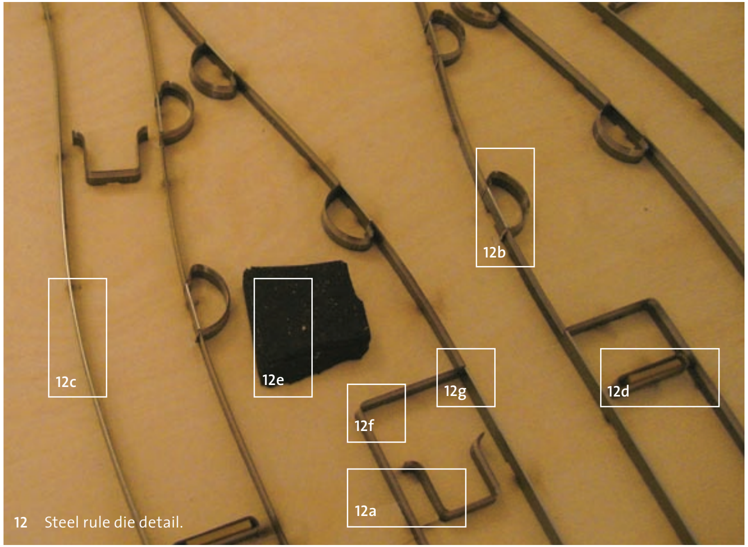
The choice of the PARCEL production principles required an early definition of the units, shortening the formal development time. The use of die cut tools for punching plastic is a very ***inexpensiv means of production with a capacity for mass production*** ↓ [P.30], strengthening the idea of PARCEL as a consumer product. The PARCEL development primarily relates the design explorations and the operation of the physical PARCEL assembly to the performative aspects of production processes and effects. At a later stage as part of this thesis, the formal development was revisited in the ***P5 PARCEL Parametric Solution Space and Fabrication design loop*** → [P.36], in which the production effects are replaced by continuous fabrication processes, allowing exploration of much higher formal variation and ***mass customization*** ↓ [P.30].


8 Electronic components.

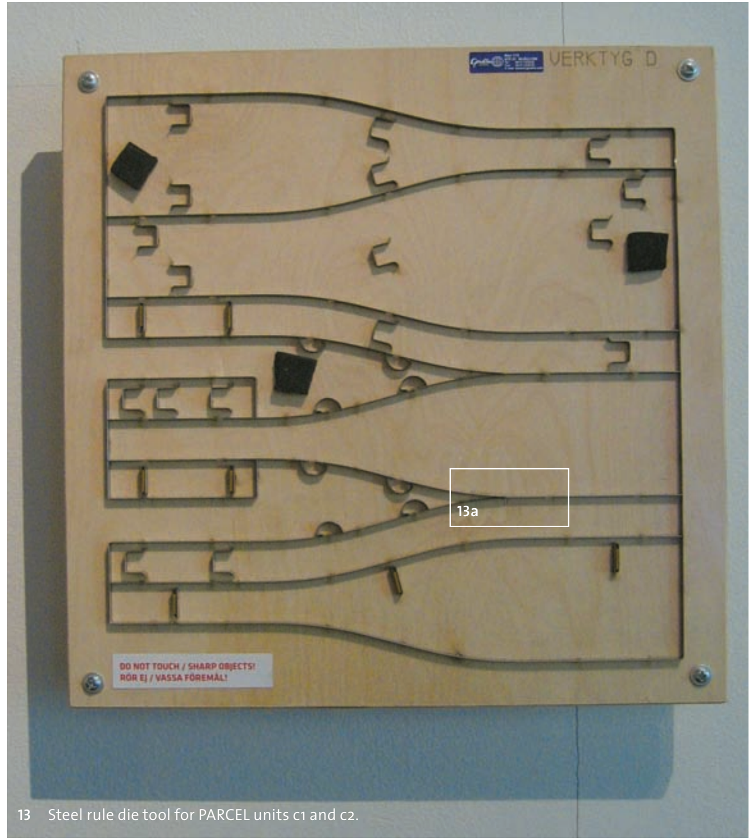

9 Conductive network.


10 Mounting resistor.


11 Electronic network.



12 Steel rule die detail.

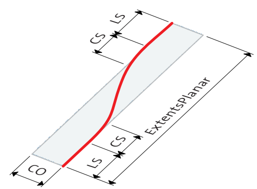


13 Steel rule die tool for PARCEL units c1 and c2.

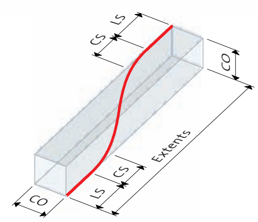
Electronic components are being prepared in **image 8**. The conductive lines for power and communication are manually placed in the form of conductive tape in **image 9**. Components are attached by conductive glue on a foundation of conductive ink in **image 10**. In the completed conductive and electronic network in **image 11**, crossing conductors are isolated from each other by regular tape. **Image 12** shows a close-up of the die cut tool for units c1 and c2. **12a** shows curved cut blades for unit border and assembly detail. **12b** incorporates the cut blade of assembly details with a score blade which allows it to be folded. **12c** is a slightly curved blunt score line blade. **12d** shows a narrow cut blade for assembly detail incorporating a thin ejection rubber. **12e** shows a singular soft closed cell ejection rubber. **12f** shows a corner with a radius for plastic extraction from tool and improved unit strength. **12g** shows a sharp inner corner of cut plate meeting a score plate. **Image 13** shows the same complete die tool. **13a** indicates a joint of two cut plates at sharp angle, continuing into a score plate.

P5 PARCEL Parametric Solution Space and Fabrication

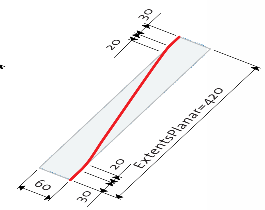
The P5 design loop is a post development of the PARCEL project enabling parametric variations of the initial configuration, in which four variables are introduced to the individual PARCEL unit. The specific form is affected, but the topological principles are identical. In analogue with the ***initial PARCEL design development*** **←** [P.14], the parametric associative model is based on the single curved fold-line. The deformation of selected geometrical parameters of this line allows great variation of its formal properties. As part of the design loop, each modeled unit has a coupled fabrication pattern, controlled by the same variables. The purpose of these patterns is to enable physical fabrication of each design variant, in which its material constrains for folding as well as other physical aspects can be tested. The representational 3D digital model features the fold line as a curve in space, while the parallel fabrication pattern includes the 2d curve needed to achieve that form through the folding of the material. Rather than using digital modeling and fabrication techniques, such as unfolding and flattening of certain types of



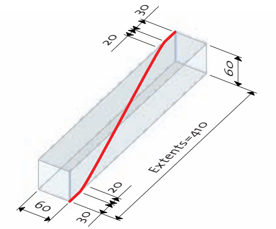
1a planar curve.



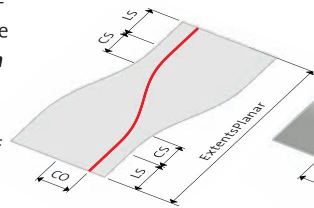
1b folded curve



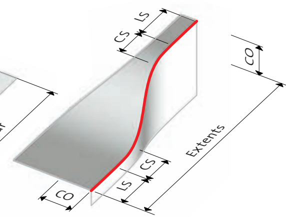
2a planar curve instance



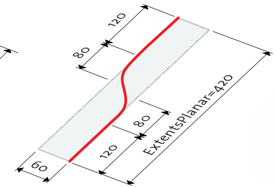
2b folded curve instance



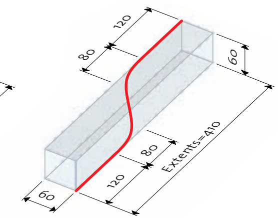
1c planar curve of surface



1d curve as fold line

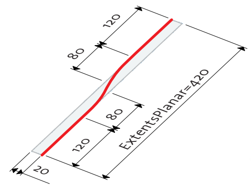


2c planar curve instance

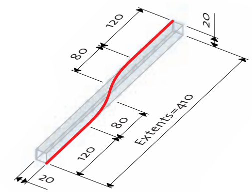


2d folded curve instance

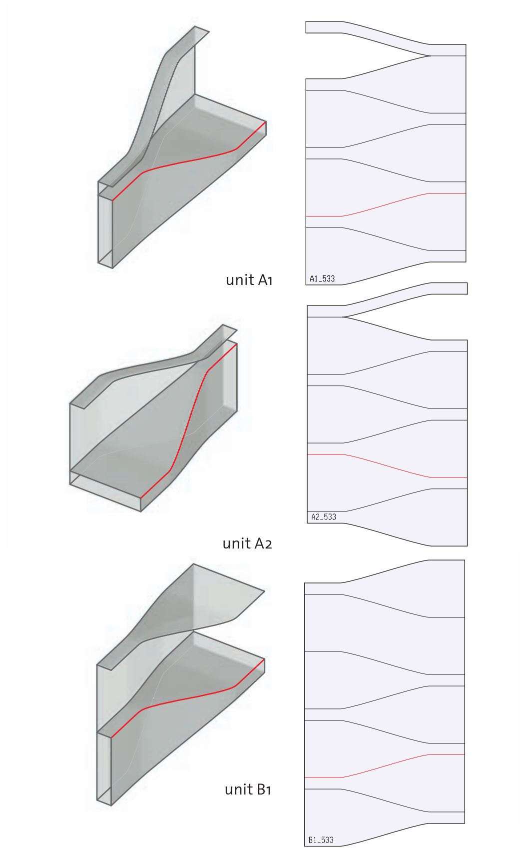
The foundation of the PARCEL unit is the single curve that defines the fold line. Its curvature gives structural integrity to the panel, as well as formal characteristics. This curve is defined by three variables. *CurveOffset (CO)* indicates the offset between each end of the unit in both the planar unfolded unit and the folded version. *LineStraight (LS)* defines the straight part of the folding line. *CurveSlack (CS)* defines the curvature of the foldline, ranging from a straight line to extreme bulginess. The fourth variable *ExtentsPlanar* is given by the chosen material width, with the folded result being *Extents*. Each curve has a folded and planar version.

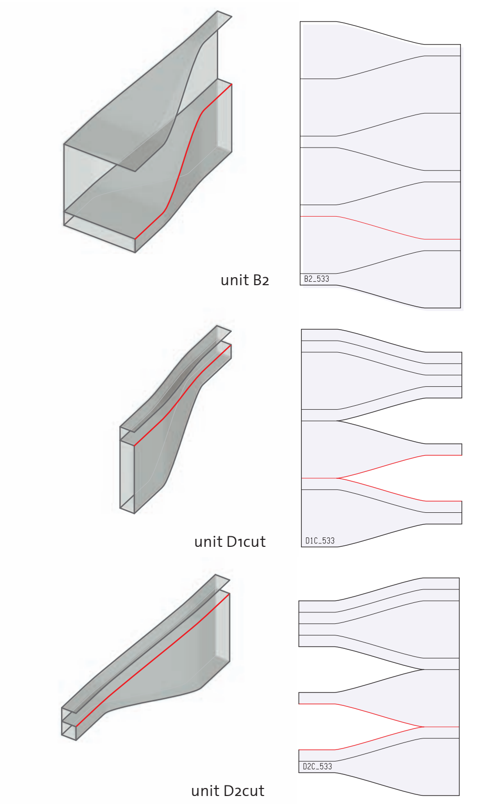


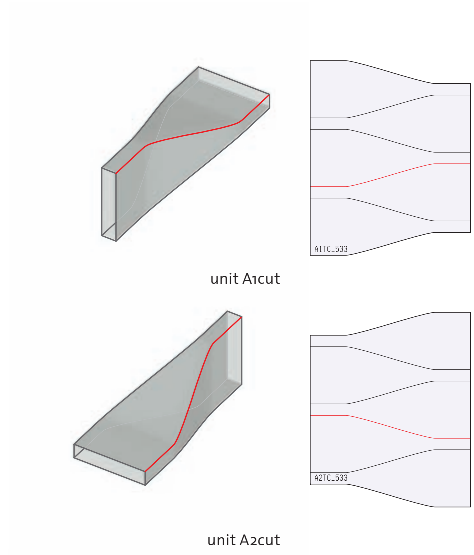
2e planar curve instance



2f folded curve instance





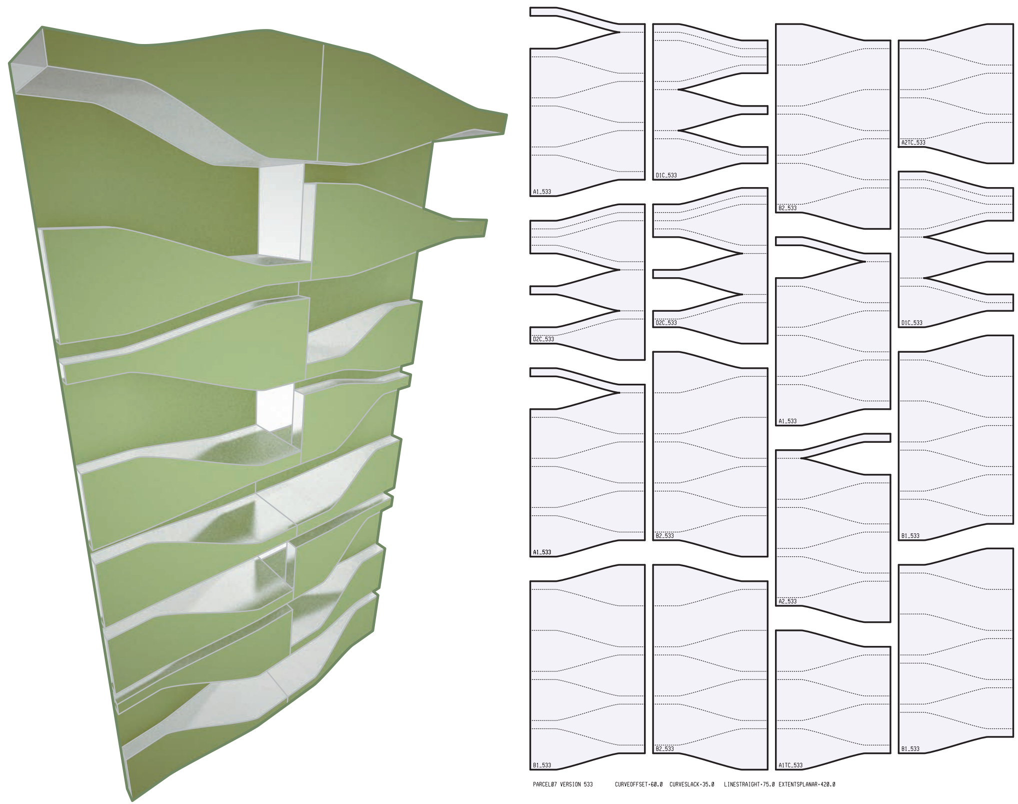


3 Folded representations and fabrication patterns of selected panel assembly, instance 533.

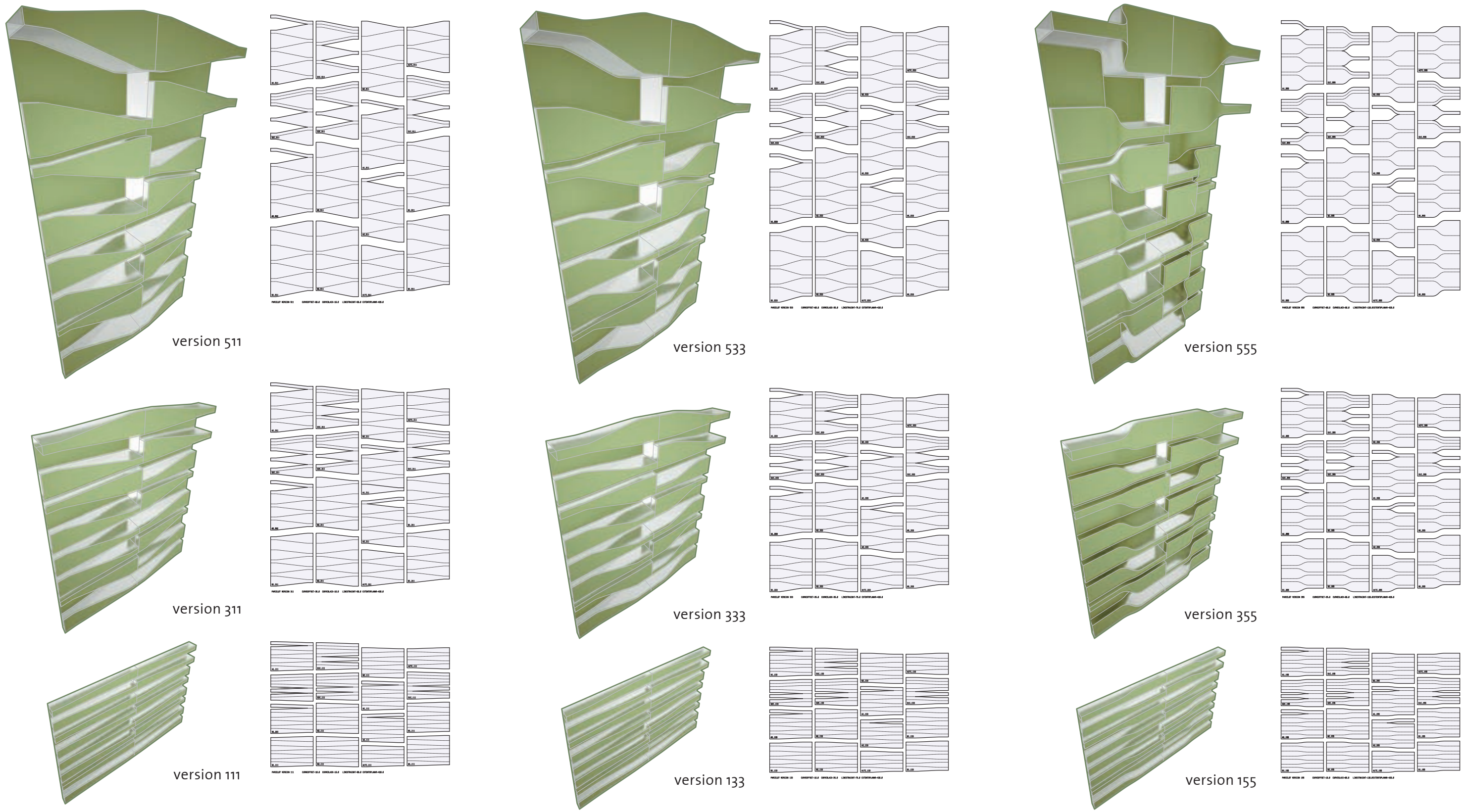
Each modeled PARCEL unit has a coupled fabrication drawing, the planar equivalent of the folded model. The fabrication pattern is developed as a separate model driven by the same parameters, rather than an “unfolded” version of the unit. The parametric software used allows for the simultaneous update of both model and fabrication drawing, allowing digital tests of configuration followed by material tests of fabricated units produced in a laser cutter. The fabrication patterns are simplified versions of the original PARCEL production template. Units A1cut, A2cut, D1cut and D2cut are custom units reflecting the specific assembly used in this development.

singular surfaces, the fabrication patterns are designed in parallel with the representational models, through the establishment of relations between the folded version and the flat pattern. To a certain extent, the fabrication aspects simulate future production, and could be developed further to include the additional production information used in the original PARCEL development.

A specific assembly was configured in order to understand how each design instance operates in context. The individual units of the assembly are still linked to their respective fabrication patterns, further refined through a composite pattern in which the distance between the individual patterns is updated with the change of the curve parameters, in particular the **CurveOffset** variable explained in **image 1**. This allows for material efficiency in the fabrication of different design variants in parallel. The parameters have different characteristics. **CurveOffset**, being the most significant for the spatial extents, changes the proportions of each unit, which has great impact on the resolution of the assembly as well as the depth of the overall paneling system. The combination of **CurveSlack** and **LineStraight** sets the intensity of the curvature, and therefore has the strongest impact on the formal identity of the assembly.



4 PARCEL parameter variation version 533.

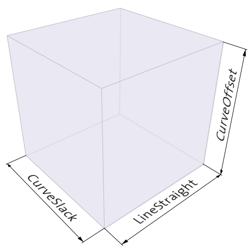


5 PARCEL selected fabrication patterns.

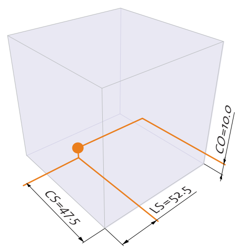
The three parameters affecting the formal characteristics of each PARCEL unit can be collected in a ***3 dimensional design solution space*** ↓ [P.17 | P.18 | P.26 | P.30], in which xyz represents each of the three parameters **CurveSlack**, **LineStraight** and **CurveOffset**. Within this design space, any given proposal is referred to as a design instance, a PARCEL variant with specific formal characteristics. The original PARCEL design is but one instance within this design space. The limits of the three applied parameters were chosen intuitively based on when they either make little or no difference from previous settings, or when they become too extreme in regards to the overall form as well as for fabrication purposes. While the design space allows for virtually infinite gradient instances within the selected limits of the parameters, set thresholds were chosen for the purpose of evaluation of the whole range. A range of five cases of each parameter gives 5x5x5 = 125 instances. The extremes and midranges of these sets were selected for fabrication, giving a 3x3x3 = 27 instances. The parametric model set up in GenerativeComponents also used Excel spreadsheets to organize the sets of parameters and the link between the digital models used for representation and the fabrication patterns. The naming of the selected instances, as presented in the images, also identifies the three parameters. In the name ABC, A corresponds to shifts in **CurveOffset**, B to

parameters/vs	111	211	311	411	511	121	221	321	421	521	131	231	331	431	531	141	241	341	441	541	151	251	351	451	551
CurveOffset (10-60)	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0
CurveSlack (10-60)	10,0	10,0	10,0	10,0	10,0	22,5	22,5	22,5	22,5	22,5	35,0	35,0	35,0	35,0	35,0	47,5	47,5	47,5	47,5	47,5	60,0	60,0	60,0	60,0	60,0
LineStraight (30-120)	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0
ExtentsPlanar (420)																									
parameters/vs	112	212	312	412	512	122	222	322	422	522	132	232	332	432	532	142	242	342	442	542	152	252	352	452	552
CurveOffset (10-60)	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0
CurveSlack (10-60)	10,0	10,0	10,0	10,0	10,0	22,5	22,5	22,5	22,5	22,5	35,0	35,0	35,0	35,0	35,0	47,5	47,5	47,5	47,5	47,5	60,0	60,0	60,0	60,0	60,0
LineStraight (30-120)	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5	52,5
parameters/vs	113	213	313	413	513	123	223	323	423	523	133	233	333	433	533	143	243	343	443	543	153	253	353	453	553
CurveOffset (10-60)	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0
CurveSlack (10-60)	10,0	10,0	10,0	10,0	10,0	22,5	22,5	22,5	22,5	22,5	35,0	35,0	35,0	35,0	35,0	47,5	47,5	47,5	47,5	47,5	60,0	60,0	60,0	60,0	60,0
LineStraight (30-120)	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0	75,0
parameters/vs	114	214	314	414	514	124	224	324	424	524	134	234	334	434	534	144	244	344	444	544	154	254	354	454	554
CurveOffset (10-60)	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0
CurveSlack (10-60)	10,0	10,0	10,0	10,0	10,0	22,5	22,5	22,5	22,5	22,5	35,0	35,0	35,0	35,0	35,0	47,5	47,5	47,5	47,5	47,5	60,0	60,0	60,0	60,0	60,0
LineStraight (30-120)	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5	97,5
parameters/vs	115	215	315	415	515	125	225	325	425	525	135	235	335	435	535	145	245	345	445	545	155	255	355	455	555
CurveOffset (10-60)	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0	10,0	22,5	35,0	47,5	60,0
CurveSlack (10-60)	10,0	10,0	10,0	10,0	10,0	22,5	22,5	22,5	22,5	22,5	35,0	35,0	35,0	35,0	35,0	47,5	47,5	47,5	47,5	47,5	60,0	60,0	60,0	60,0	60,0
LineStraight (30-120)	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0	120,0

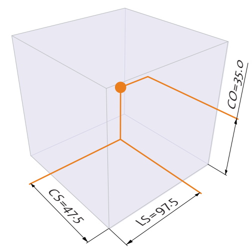
6 ***Spreadsheet parameters*** ↓ [P.26] for 125 selected instances of solution space, with three clarifications below.



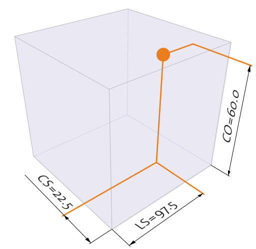
7a parameter space.



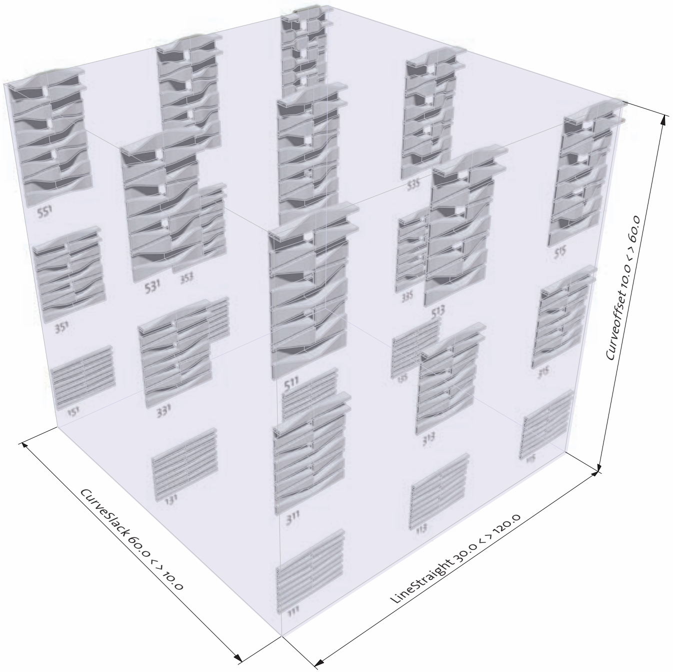
7b 142 instance.



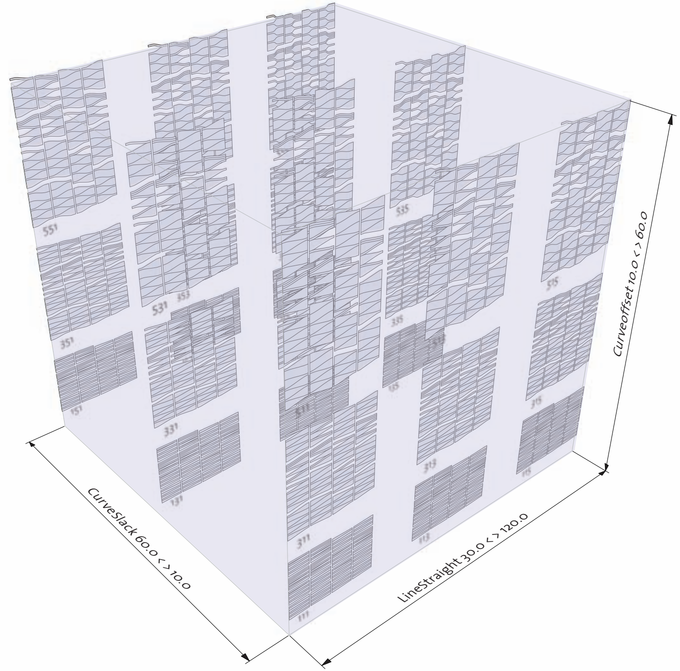
7c 344 instance.



7d 524 instance.



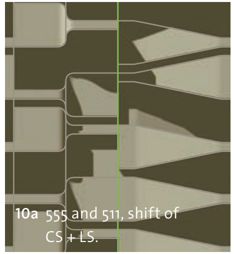
8 PARCEL 27 selected instances in model solution space.

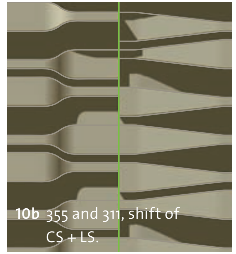


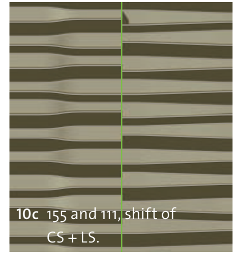
9 PARCEL 27 selected instances in fabrication pattern solution space.

A selection of parameters within the design solution space is represented in 2D in the **image 6** spreadsheet, used to feed the GenerativeComponents parametric model which produced both 3D-models and 2D fabrication patterns. **Image 7a** shows the definition of the design space axes with the *CurveSlack*, *LineStraight* and *CurveOffset* parameters as XYZ, while *7b*, *7c* and *7d* show the location of the instances *142*, *344* and *524* within the space (also marked in orange in image 6). The 3D design solution space in **images 8+9** furthers the understanding of the impact of the change of one, two or three parameters and the comparison between the 3D-representations and the fabrication patterns. The fixed *ExtentsPlanar* parameter makes the fabrication patterns equally wide (unlike the folded assemblies), while the change of *CurveOffset* in the vertical axis makes the height of each folded assembly as well as pattern similar for each horizontal layer.

shifts of **CurveSlack** and C to shifts of **LineStraight**. Each design variant can only be fully combined with other units of the same instance in each vertical assembly, since the exact form of the curvature must correspond for a perfect fit. Different instances can be combined in a horizontal fashion, introducing a new transitionary effect of variation along the length of a larger panel assembly. The different parameters have different formal effects on these transitions. Shifts of **CurveSlack** and **LineStraigth** keep the modular distances in height and depth the same between each vertical assembly. Shifts of **CurveSlack** produce transitions from more to less curvature, while changes of **LineStraight** plays with the relation between completely horizontal lines and the diagonals (**images 10a–10c**). Shifts of **CurveOffset** change the modular distances, making the pattern discontinuous between the vertical assemblies, but depending on the steps of variance between each instance, continuous lines may emerge throughout the overall panel nonetheless. The **CurveOffset** parameter also shifts the resolution of the panel, in depth and vertical directions (**image 10d**). The combination of different PARCEL design instances in this manner opens a door to additional possible configurations, as an extension of the original based the original ***recombinatorial potential*** ← [P.22].


10a 555 and 511, shift of CS + LS.


10b 355 and 311, shift of CS + LS.


10c 155 and 111, shift of CS + LS.

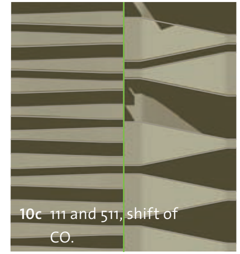
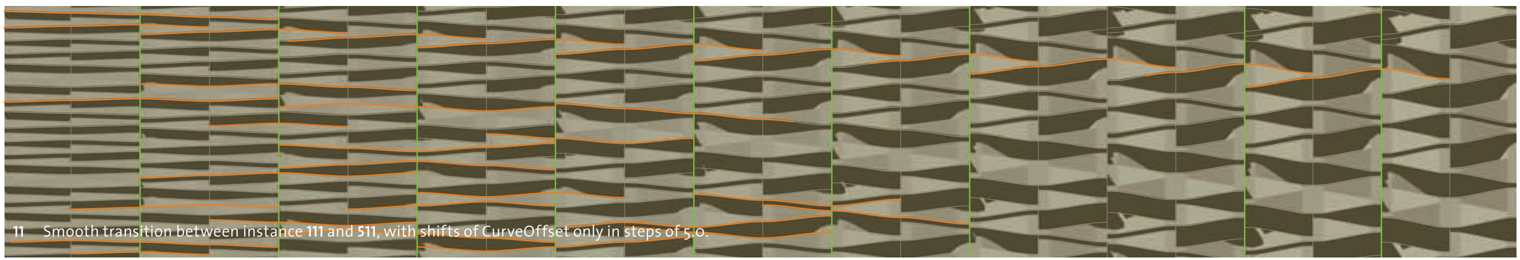
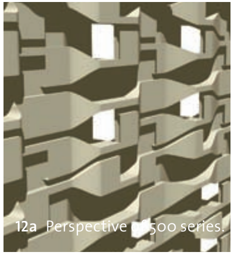

10c 111 and 511, shift of CO.

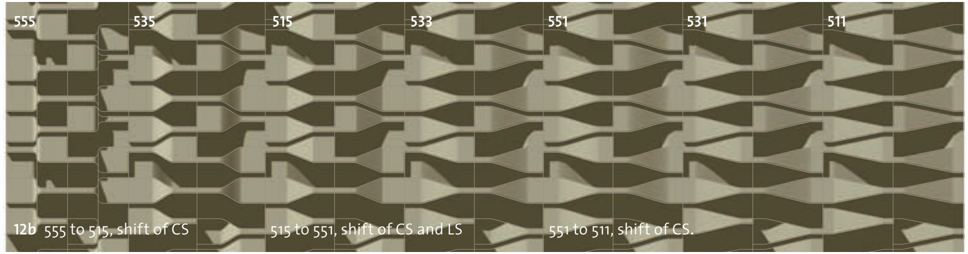
Image 10 shows the extremes shifts of parameters with no transitionary effect. In **10a**, **10b** and **10c** the modular extents are constant, making the curves continuous while having a dramatic shift.
In **10d** the shift of *CurveOffset* makes the curves discontinuous. When using smaller *CO* increments, continuous lines emerge, as shown in **image 11**. The shift also allows for a change of resolution, which in part manifests as a diagonal line of pattern repetition. Green lines indicate borders between vertical assembly instances. Orange lines indicate continuous lines between different instances despite shift of *CO*.


11 Smooth transition between instance **111** and **511**, with shifts of CurveOffset only in steps of 5.0.

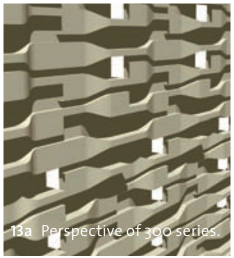


12a Perspective of 500 series.

Image 12a+b: The collections of instances can be grouped into series, depending on what parameter is constant. The *500*, *300* and *100* series differs in *CurveOffset* which emphasizes the differences in vertical resolution, ranging from a deep surface articulation with dramatic shadows in the 500 series, to a flatter panel with a blending of surface and shadow.

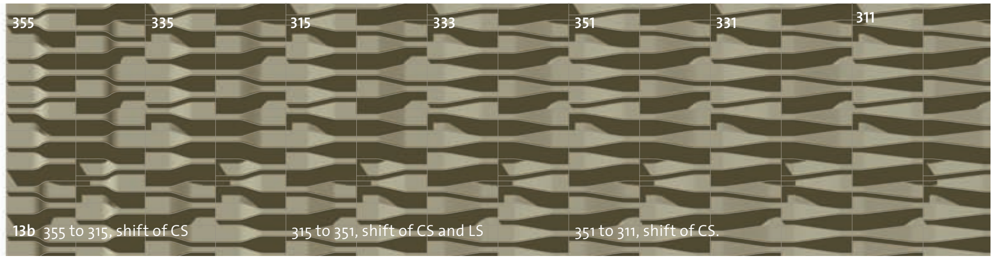


12b 555 to 515, shift of CS 515 to 551, shift of CS and LS 551 to 511, shift of CS.

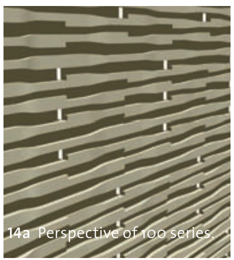


13a Perspective of 300 series.

Image 13a+b: The changes of *CurveSlack* changes the inflection of all surfaces, reflected in the shift from sharp to sifter shadows across the vertical surfaces. The LineStraight changes, between instances *X15*, *X33* and *X51*, narrows down the flat parts in relation to surfaces with curvature.

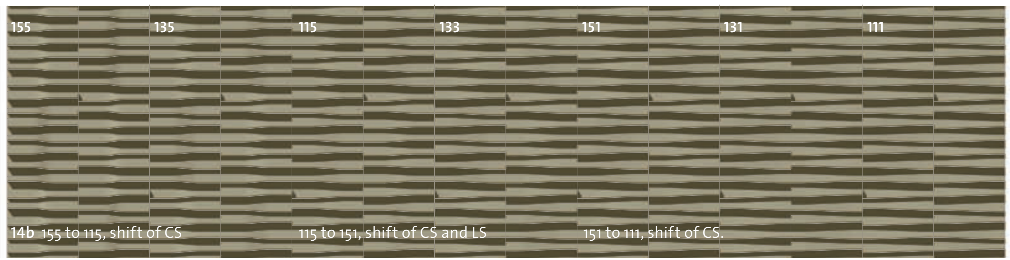


13b 355 to 315, shift of CS 315 to 351, shift of CS and LS 351 to 311, shift of CS.



14a Perspective of 100 series.

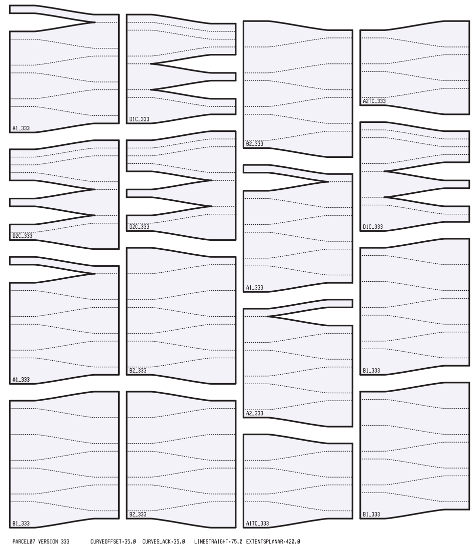
Image 14a+b. The set-up presented is based on a fixed value to the *ExtentsPlanar* parameter, while the *Extents* parameter is dependent on the all other parameters. This is reflected in the changes of width between each assembly instance, explicitly seen in the overall difference in width between the panels in image **12b**, **13b** and **14b**.



14b 155 to 115, shift of CS 115 to 151, shift of CS and LS 151 to 111, shift of CS.

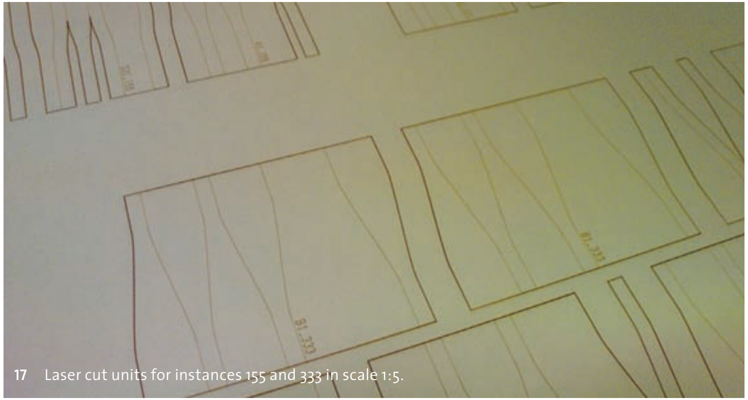
The design development presented in the Parametric Solution Space and Fabrication design loop revisits the PARCEL project, and in particular the formal design process. While the original formal studies were forced to rapidly find an adequate exact shape after the principle for folding and recombination had to be found, the parametric set-up presented here investigates these issues more exhaustively. It makes use of the production aspect of the die cut punching tool, but when applied to the principles of a laser cutter, there is an opportunity to look at its potential for ***fabrication*** ↓ [P.28], in the sense of exploring multitudes of formal variations. In this respect, the generation of design instances in digital 3D-models work together with the physical models fabricated through the means of the laser cutter in the formal exploration. The digital models allow for more rapid trials of combinations of multiple instances, while the physical prototyping of assemblies also looks at the folding capacity of the material. It also functions as an aid in the communication of the formal qualities and fabrication principles to outside parties. The adapting sets of fabrication patterns for each assembly instance simulate production aspects to some extents. While the assembly detailing cannot be included in the scale models, the same principles used in the original PARCEL design can be applicable to any of the new instances.

Image 15 and **17** show the cutting lines and fold lines for fabrication, as well as etching patterns for annotation to aid the assembly and later identification of each instance. The fabricated model shown in **image 16** suggests the material qualities of the assembly that adds information that cannot be covered by the more perfect digital models. The annotation is automatically generated within the GenerativeComponents parametric model, and incorporates each unit name and the instance index number, such as *A2_555*. **Image 18** shows physical models from the original PARCEL development in scale 1:1, **image 19** shows fabricated models in 1:5. **Image 20** shows the different material consumption for different instances .

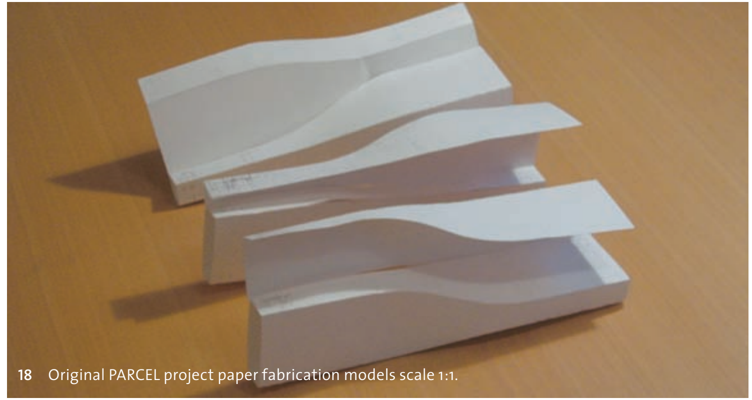


15 Fabrication pattern for instance 333 assembly.

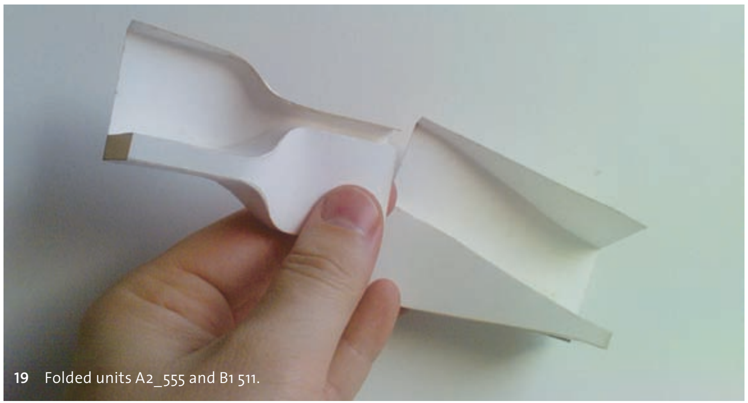
16 Assembly instance 333 in scale 1:5.



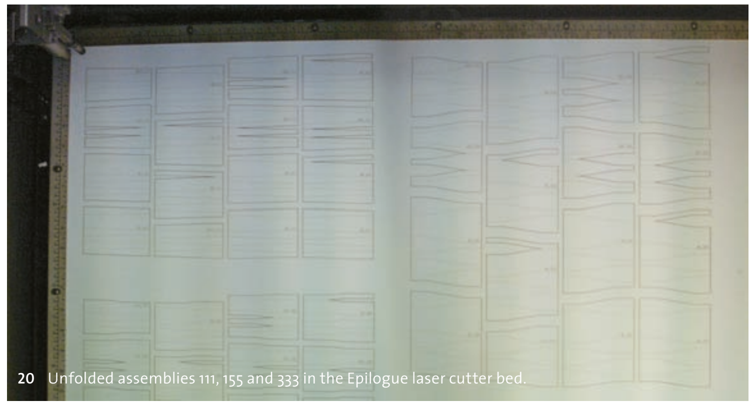
17 Laser cut units for instances 155 and 333 in scale 1:5.



18 Original PARCEL project paper fabrication models scale 1:1.



19 Folded units A2_555 and B1 511.



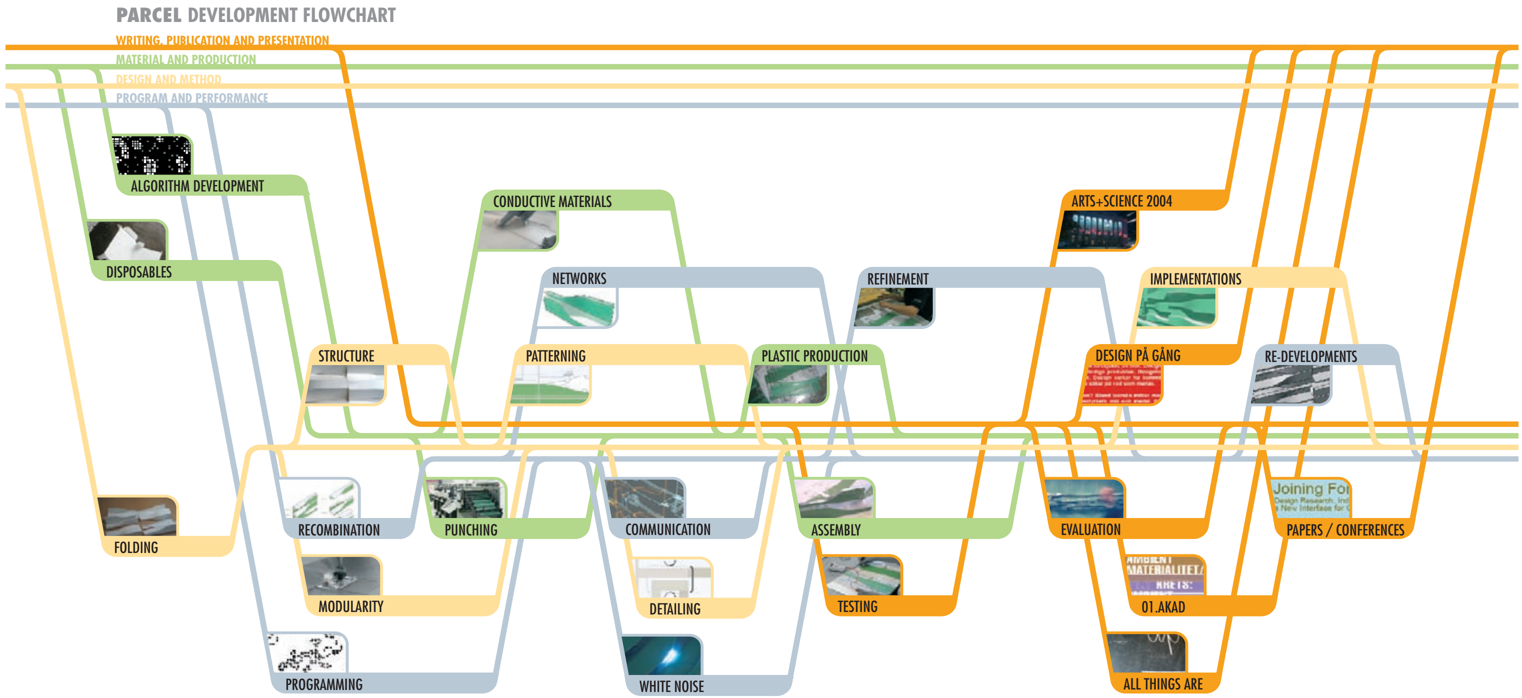
20 Unfolded assemblies 111, 155 and 333 in the Epilogue laser cutter bed.

P6 PARCEL Performance

Performance within the PARCEL project is inherent in all its instances, including early prototypes and later physical assemblies. In this sense, its performance has been relevant in all steps of the design development, as well as in the experience and evaluation of its effects as a whole. The PARCEL development flowchart ***maps different distinguishable sub-processes*** ↓ [P.53] through the formation of the projects, and suggests four different strata. The *Design and Method* stratum makes up the pulse of the project in a more classical sense, including form-giving and design of the material parts, conceptual ideas of modularity, patterning on different levels and detailing that solves joints and links in a functional, as well as aesthetical manner. The *Material and Production* stratum includes research and investigation of ***material performance*** ↓ [P.34], potential production methods, principles for assembly based on the design development, as well as research into applicable programming code for the PARCEL responsive behavior. As implied by its name, the *Program and Performance* stratum presents the clearest cases of distinct performance giving feedback during the process, including control system code development, electronic hardware testing, electric network design, recombinatorial capacity of the PARCEL units and later re-developments. The *Writing, Publication and Presentation* stratum is considered a vital part of the project as a whole, due to its possibilities to evaluate not only the effects of the final formal design and responsiveness, but also vital steps of the design development though representations. The complete presentation of the PARCEL project in this thesis is the latest and most detailed part of this stratum.

As the flowchart suggests, the PARCEL project was actually formed when the parallel investigations in these strata start to interfere with each other. This is a result of the performance of the numerous prototypes and processes that were initiated, and in particular when these prototypes were informed by each other. The strata defined in the diagram existed in the work of the Krets research group before the PARCEL project, but were articulated through the development of the project, and have been continuously explored in the work of Krets as well as in the individual work of its members later.

A number of concepts are relevant to the performance of each part of the design development, as well as the capacities of interactions between these parts. ***Remediation*** ↓ [P.31], understood as the continuous exchange of content between different media in which the characteristics of the former may be retained in the latter, becomes crucial as prototypes are regarded as existing in multiple media simultaneously. It operates in physical and digital models, through drawings and diagrams to operational physical assemblies. The remediation between each prototype also establishes conceptual and material links between the different issues explored. The structural integrity of each unit was studied in folded plastic and cardboard mock-ups, which when unfolded gave the restrictions on how the printed network could be imprinted, and allowed the distribution of detailing for closing each unit as well as connecting units to each other. This required iterative shifts between physical model and digital drawing, to mediate the structural aspects of paper/plastic and the precision of digital models and CAD drawings. The conductive network was studied in drawings, with parallel digital model studies to explore the ornamental effect on the folded unit and the overall installation network. The detailing of physical connectors were also designed to provide electronic connection for power and communication between each unit, and the conductive capacities of conductive paint, glue and tape were explored though material tests. The drawn pattern for each PARCEL unit as used as a master for the ***die cut and scoring tool*** ← [P.32], setting cuts



1 PARCEL Development Flowchart.

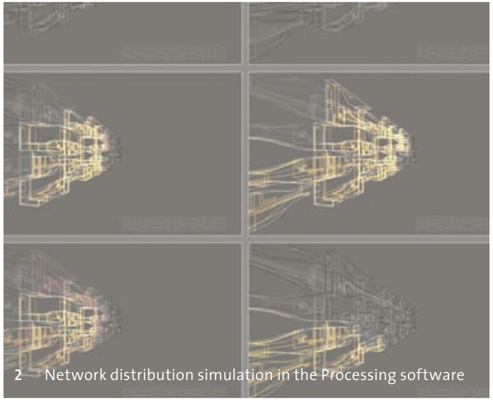
Image 1 shows show a reconstruction of main areas of design and research in the PARCEL project development. The four main strata of development include *Program and Performance, Design and Method, Material and Production and Writing, Publication and Presentation*, Each of these strata have a number of development loops. The initial studies were more unrelated, exploring several issues not yet combined into a project in parallel. Over time, the project achieved its formal characteristics, and the design development moved into problem solving and detail design, as well as studies of the responsive behavior. The presentation of the project in exhibitions and conferences were also regarded as important parts of the development.

and fold lines, operating as the original for the printed circuits and color scheme and as an instruction for the placement of electronic components. The pattern is, through the production steps, remediated into the physical artifact in a 1:1 inscription. The responsive remediation of ***sounds picked up in the immediate surroundings*** → [P.52] of the PARCEL installation requires real-time remediation of sound into code and signals, in order to be re-modulated and re-emitted as light and sound at another location.

Fabrication, in the sense of creating new form through design integrated with techniques often used for manufacturing, is an integral part of the design process. The initial trials utilizing physical models link structural performance with geometries based on the folding lines and the material properties of paper, resulting in the fabrication of many design variants valuable for the initial form evaluation. ***Fabrication also suggests the creation of fiction*** ↓ [P.28], suitable to establish plausible models for simulation of effects and performance. The PARCEL units, integrating the formal aspects with the conductive capacity, can be seen as fabrications in themselves, exploring the potential of responsive control systems interfering with physical expressive form. This fabrication process was, apart from the formal design steps, especially dependant on the development of the conductive network with the integration of the different conductive materials, the deployment of the network within the units and the development of the control algorithms through simulations in the software Processing and hardware tests. The ***P5 PARCEL Parametric Solution Space and Fabrication*** ← [P.36] is the clearest take on the fabrication concept however, in the way it sets up a design system that explores a potentially infinite number of PARCEL form variants within a defined design solution space, reproduced both as digital geometries and as laser cut physical models.

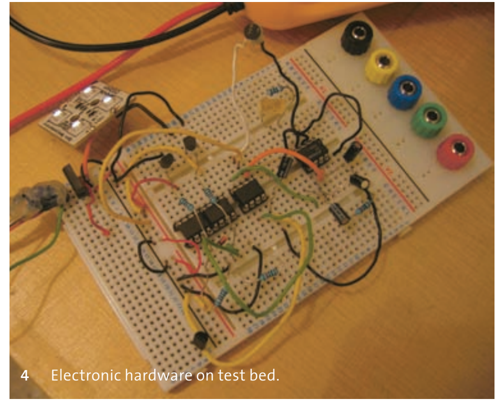
The model used for the simulations of the network performance in the Processing software is parametric in itself, presenting the way signals disperse throughout a panel assembly triggered by user input. The design and simulation systems established ***constraints and defined drivers*** ↓ [P.16] for the design development in multiple areas. The material aspects of PARCEL allowed for other more direct studies that complemented this work. The use of conductive materials normally used for shielding sensitive electronic equipment rather than power and communication distribution required numerous trials to ensure their performance and reliability. A special circumstance was the need to combine conductive glue (PVC plastic cannot be soldered), tape (for longer distances of power distribution) and paint (for simulating print and creating free form patches for joints and component attachment), which required additional testing. Simple LEDs gave visual confirmation in conductive test, volt meters allowed for more rigorous quantitative evaluation. Resistance is building up over distance in these conductors, but the materials were still regarded to be adequate for the purposes of the project. The performance of the electronic control systems, based on programmed cellular microprocessors and additional standard components, were explored in a test bed controlled by PC coding software. Additional testing of conductive performance was done continuously during the production and assembly. While the PARCEL development in many other areas depended on visual and intuitive design decisions, this part of the development was benefited by very precise quantitative feedback.

Image 2 shows screenshots from simulations of network distribution in real time, performed in the Processing software. **Image 3** shows tests of conductive glue, ink and tape when combined and attached to plastic materials. The material is often used in shielding of electronic components rather than for power and communication. **Image 4** shows the test bed tests of the electronic hardware for the cellular control system based on PIC 12F629 Micro Controllers. Electronic components were attached to the PARCEL units by conductive glue, as with the resistor in **image 5**. Continuous conductive tests of all parts were done during the assembly as shown in **image 6**. **Image 7** shows several unfolded PARCEL units with completed control circuits.

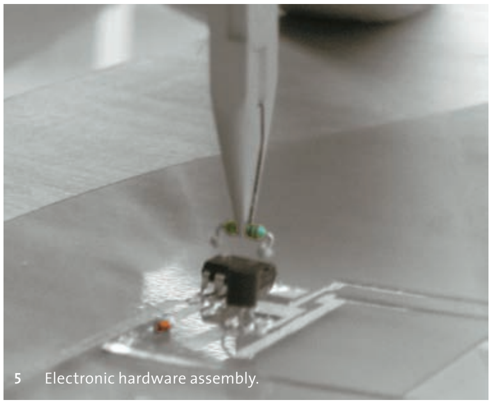


2 Network distribution simulation in the Processing software

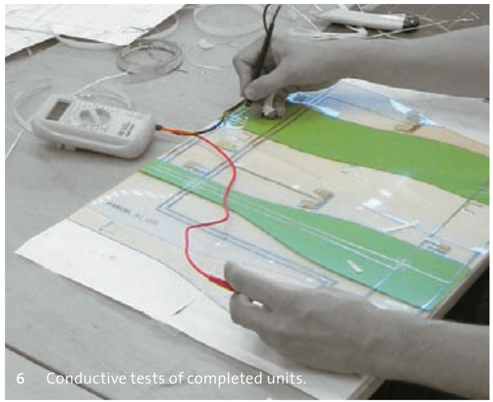
3 Trials of conductive capacities.



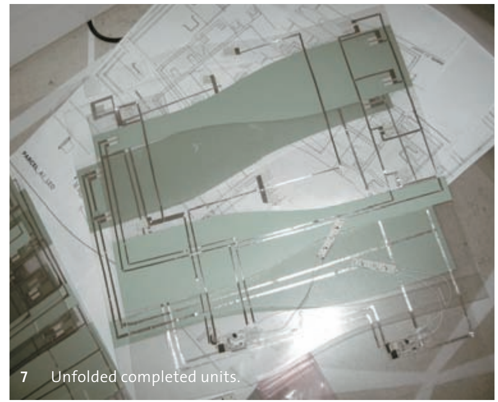
4 Electronic hardware on test bed.



5 Electronic hardware assembly.



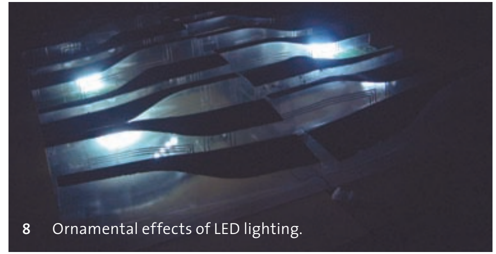
6 Conductive tests of completed units.



7 Unfolded completed units.

The immaterial reactive characteristics of PARCEL are based on white noise, which is often used to control sound con-ditions in an environment. Surrounding sound is picked up locally through microphones and dispersed to other units of the installation through the integrated network. During this transfer, the sound signal is transformed by white noise and emitted through loud speakers and LED lighting, thus establishing local environments. The interchangeable PARCEL units, each with specific formal and operational characteristics, allow dynamic recombination by users/visitors while the installation is in operation. The simultaneous physical and electronic connection between each piece allows recombination when PARCEL is in operation, reconfiguring the striated pattern of the complete installation and changing the emergent behavior of the local environments.

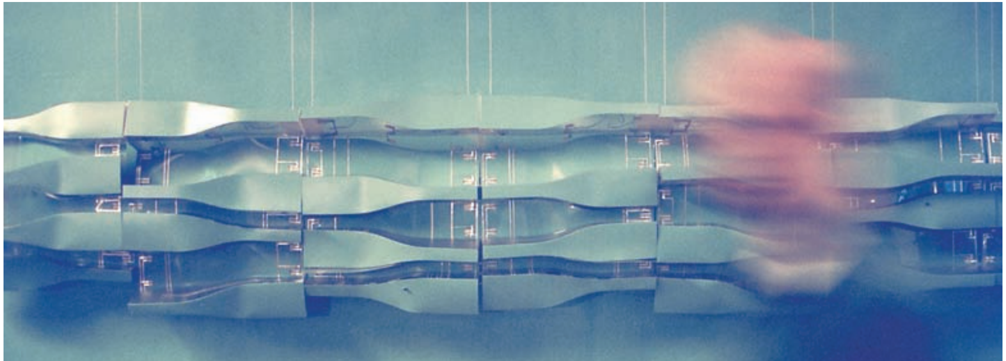
While the physical assemblies of the final physical prototypes of the PARCEL project allow the experience and assessment of the integrated performance of the formal aspects, control system behavior and user interaction enabled by the potential for recombination, the effects of the PARCEL installation may also be considered in its individual aspects, especially in regards to local contextual conditions in presentations. While operating with no other light sources, the integrated LED lighting system enhances the ornamental aspects of the assembly. In this way the conductive network, the translucent aspects of the frosted PVC and the painted surfaces as opaque shading become more present in the strong visual contrast. The conductive network adds another resolution to the ornamental effects of the physical units. The differentiation of the LED light shifts the intensity and focus of this emerging pattern over time. In an environment with other light sources, the internal light may be visible primarily on the folded glossy surfaces between the open box parts, while external sources light the outer surfaces of the open box front panels. This creates shifts of light temperature and color over different areas of the PARCEL assembly (**image 9**) as well variations in dynamic change as the PARCEL responsive behavior changes the LED lighting. In a well lit area, the color scheme becomes more important. The responsive behavior was not operational in the first presentation at the Stockholm Concert Hall, but the selected PARCEL color interfered directly with the saturated foyer walls. Apart from the formal play of depth of surfaces, which mirrors the color shifts inherent to the wall, the surface curvature shifts the perception of the color scheme over the panel assembly. The experience of the ornamental patterning effects and the formal striation at a slightly larger scale also depends on the location of the viewer. A front view at a distance exhibit the orna-



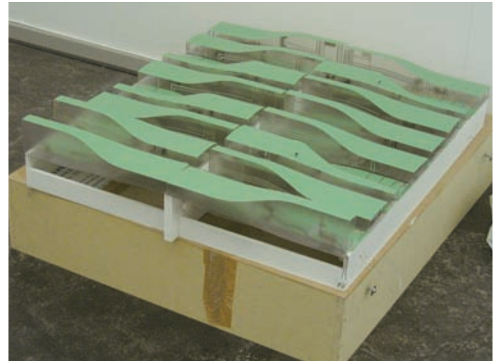
8 Ornamental effects of LED lighting.

9 Assembled unit on display at Kulturhuset Stockholm.

In **Image 8** the ornamental effect of the conductive network is reinforced with LED back light. **Image 9** shows the combined effect of internal LED and external light sources. The installation at the Stockholm Concert Hall in **image 10** emphasizes the interference between the PARCEL printed color and the Concert Hall wall color scheme. **Image 11** shows the mounted PARCEL assembly on its transport box. In the overall Krets exhibition space at the Lunds Konsthall (**image 12**), the PARCEL assembly was framed by additional printed representations (**image 13**). The **image 14** display also shows the included assembly drawing handouts, allowing visitors to make their own PARCEL paper models.

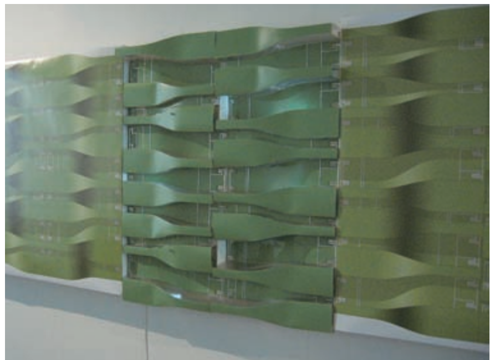


10 The assembly for the Stockholm Concert Hall.



11 Mounted PARCEL assembly on transportation box.

12 The assembly at the AKAD at Lunds Konsthall exhibition.



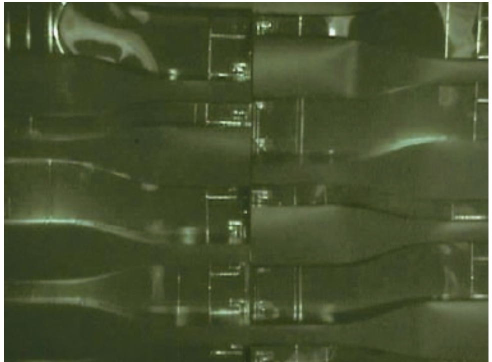
13 The assembly at the AKAD at Lunds Konsthall exhibition.

14 PARCEL production drawing handout at Lunds Konsthall.

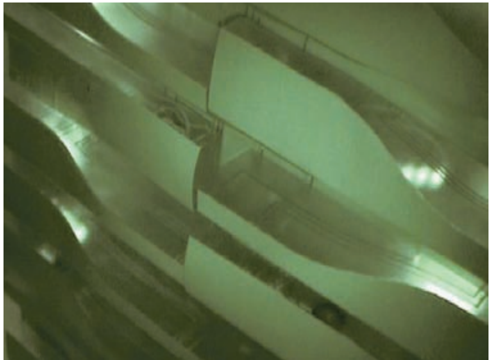
mental network on the glossy back surfaces lit by the LED light (**image 16**), while a close up view allows a direct observation of the LED filtered by the translucent plastic and ornamental conductive network (**image 18**). The responsive aspects of PARCEL, with local audio input triggered by a curious viewer, further enhances these qualities as variations in light and sound behavior is linked to the position of the observer.

The direct ***performance*** ↓ [P.16 | P.26 | P.40] of the PARCEL installed panel is affected by its context. There are different ways of establishing this context. On a basic level, PARCEL has been presented in different locations and made mobile by as an operational assembly with a customized transport box. On a conceptual level, the PARCEL units were meant to be acquired by a user separately as consumer items for application in private homes, collected for later assembly. While this has never been fully explored, the *AKAD at Lunds Konsthall* exhibition featured handouts with a full set of PARCEL units, allowing a visitor to cur out and fold their own cardboard unit models, with the electronic network as an inert ornamental pattern.

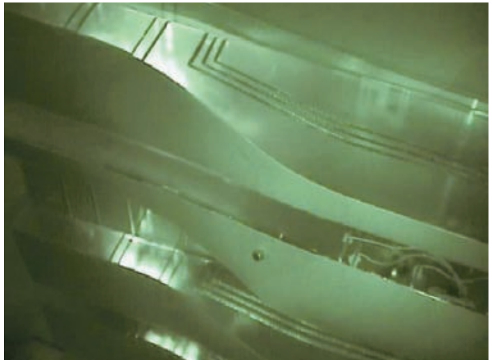
15 Video still, partial external light.



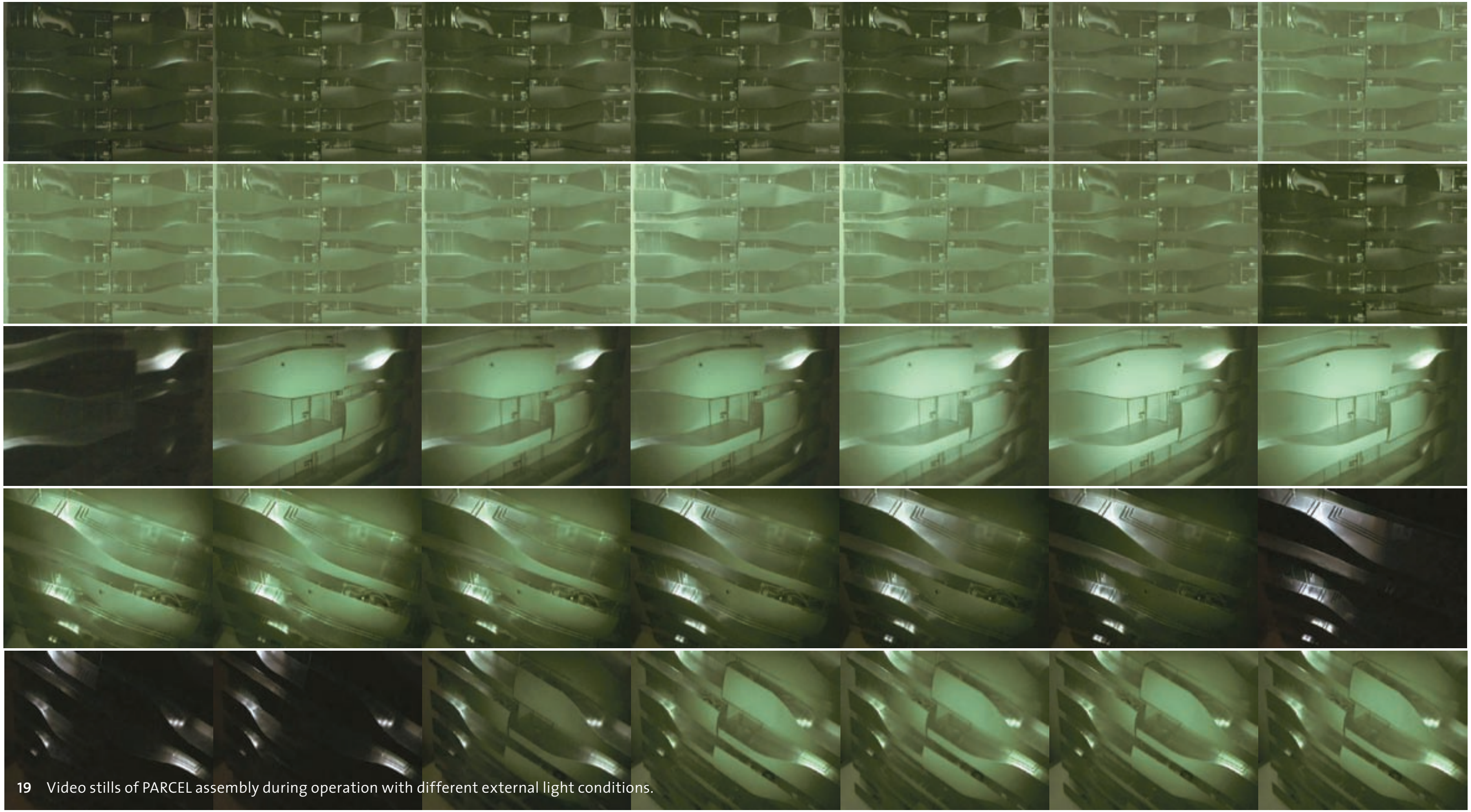
16 Video still, minimum external light.



17 Video still, partial external light.



18 Video still, partial external light, ornamental effect.



19 Video stills of PARCEL assembly during operation with different external light conditions.

SplineGraft
Design Project

The SplineGraft project sets up a kinetically reactive environment of sound dampening wall panels that are continuously reshaped by a network of actuating devices, triggered by user movement. The panels are grafted into an existing environment, supported by structural racks allowing a range of different overall panel configurations.

The dynamic effect is experienced in the form of interpolating splines, emerging in the deformation of profiled polyurethane panels through *Shape Memory Alloy* actuators. The texture is thereby reshaped in real time by the control system integrated in the structural racks; a continuous form finding process with emergent patterning effects. In return, the transformations are dispersed horizontally by the spline ridges of the panels. Supporting structural racks are assembled from cnc-milled clear acrylic units, each integrating the actuating mechanisms, milled tracks for cabling and etched nickel brass conduits for inter-unit connectivity.

The SplineGraft installation can be reconfigured to fit different spatial conditions, allowing a user to change its primary form. Any visitor stimulates its behavior, which is controlled by a continuous reformation process based on genetic algorithms. The different parts of the system communicate via wireless radio, allowing the use of a cellular intelligence distributed to each of the structural racks.

Credits:
SplineGraft is a Krets project developed by Krets partners Pablo Miranda and Jonas Runberger. Electronic hardware was developed in collaboration with Åsmund Gamlesæter. The *Shape Modulator prototype* was developed by Pablo Miranda in collaboration with the Autopoiesis & Design research project. Assisting development Team included Nick Flygt, Emma Sander, Sanna Söderhäll and Sandra Westin. The SplineGraft project development was supported by AKAD, Vitra Design Stiftung and the Helge Ax:son Johnson Foundation. The *SG3 SplineGraft Refit* design loop was developed by jonas Runberger during the SmartGeometry2007 workshop in New York.

Presentations:
SplineGraft was first displayed in the travelling exhibition Open House: Intelligent Living by Design organized by the Vitra Design Stiftung in collaboration with ArtCenter Pasadena. The first venue was part of the ENTRY 2006 at the Zeche Zollverein in Essen, Germany, 2006. SplineGraft was also featured through documentation at the Ben van Berkel and the Theatre of Immanence exhibition at Portikus, Frankfurt, 2007.

Special thanks to:
Kai Nilsson, Packningar&Plast AB and Dynalloy Inc.

Materials:
CNC-milled acrylic structural components with integrated wiring, machined polyurethane foam, etched nickel brass conductors, IR Movement Sensor, custom made PCB Cards, AVR Atmega8 Microcontrollers, Radio Modules, diverse electronic components, Flexinol® shape memory alloy actuators with protective Teflon tubes.

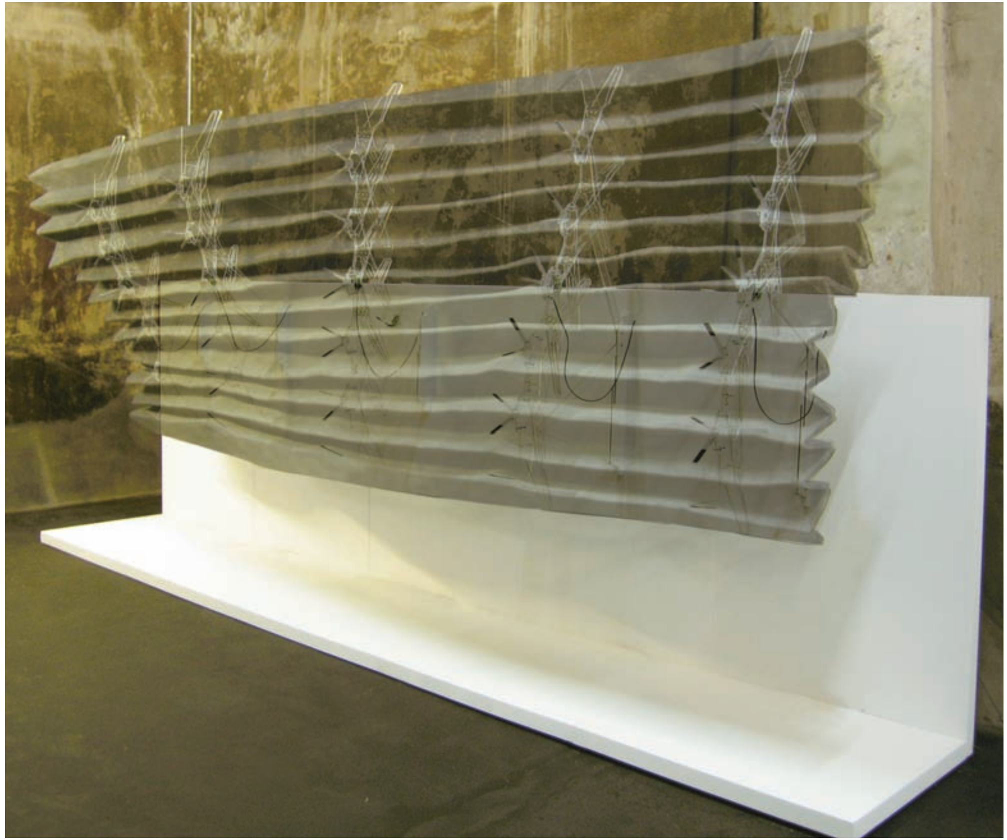
The SplineGraft design loops:
SG0 The *SplineGraft Prototypes* design loop looks at the relation between the different prototypes developed during the different stages of the SplineGraft design process.

SG1 The S*plineGraft Structural Rack Component* design loop looks at the iterative development of the structural racks, constrained by the need to assure electrical connectivity and convex/concave configuration.

SG2 The *SplineGraft Performance* design loop presents the development of the SplineGraft formal and behavioral performance, including modeling of panels, digital simulation of kinetic properties, material capacity of shape memory alloys (SMA), parametric studies of deformation of panel geometry and visual representation of kinetic transformations.

SG3 The *SplineGraft Refit* design loop prototypes alternate structural racks, based on space frame logic rather than sectional racks while retaining the planar fabrication and production principles. This required conditional tests on the component level to avoid collision of structural members.

The concept of the ***design project is further developed in the Contexts book*** ↓ [P.12 | P.44].



SG0 SplineGraft Prototypes

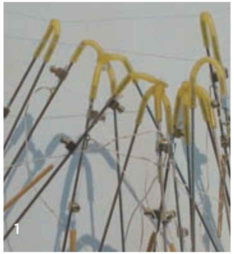
The SplineGraft was initiated by an interest in the kinetic potential in Shape Memory Alloys (SMA), also known as muscle wire, and its capacity to transform spatial conditions in real time. These materials can after deformation be restored to their original shape through heating. The necessary temperature shift can be obtained by resistance heating of the SMA using electrical currents. This was the path chosen early in the project.

The scale of the SplineGraft was based on idea from PARCEL; an interior cladding or partition-system that integrated control mechanisms and explored fabrication and production technologies. The project was initiated as a commission from Vitra Design Stiftung, based on their recognition of PARCEL as an interesting concept applicable for their *Open House, Architecture and Technology for Intelligent Living* exhibition. Vitra looked for prototypes that explored new spatial qualities derived from the innovative use of new technologies, rather than based on functional and usability issues.

The performance of kinetic actuators and material deformations were studied in a number of design environments, including digital *Non-uniform rational B-spline (NURBS) surface models, parametric design models, realtime simulation software* and *physical prototyping* with operating SMA actuators. These environments also supported the development of complementary aspects of the project, including structural support, material fabrication, as well as simulation of behavior and material tests of SMA samples. The SMAs were integrated into the structural racks, in effect creating composite actuators, in which the structural framework, the SMA material performance, the controlling electronics and algorithms, as well as the foam panel material constraints co-work to enable the SplineGraft behavior.

1. The first tests of the SMA capacity were performed in the responsive *PARCEL2 Shape Modulator* prototype. This included the affect of the user interaction with the kinetic behaviour.
2. The SMA properties were also tested at length in *kinetic physical prototypes*, including voltage / pull strength ratios and mechanical actuator components, presented in the **SG2** *SplineGraft Performance* design loop.
3. Series of digital surface models *prototyped the panel deformations* as static states, presented in the *SG2 SplineGraft Performance* design loop.
4. The dynamic properties of the panels were **simulated in real time** in the open source programming environment Processing, presented in the *SG2 SplineGraft Performance* design loop.
5. The specific form of the structural rack units were defined in *iterative sectional studies*, driven by the need to allow convex and concave configurations, presented in the *SG1 SplineGraft Structural Rack Component* design loop.
6. The structural rack also encompass the *electrical network, mapped in topological diagrams*.
7. The structural racks and the mechanical actuator set-up were developed supported by *physical prototyping*, presented in the *SG1 SplineGraft Structural Rack Component* design loop.
8. The recombinatorial aspects, electrical conduits and production patterns of the structural racks were *prototyped in digital models*, presented in the *SG1 SplineGraft Structural Rack Component* design loop.
9. The *SG3 SplineGraft Refit* design loop prototypes alternate structural racks.
10. The *fabrication methods* of the polyurethane foam enabled folding principles as well as rolling for transportation.
11. The *integrated SplineGraft physical prototype* was first tested and presented at the Open House exhibition.

The concept of ***prototypes is further developed in the Contexts book*** ↓ [P.13 | P.22 | P.26].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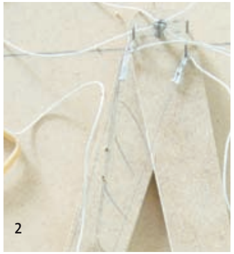
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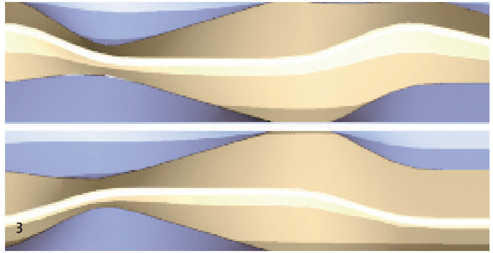
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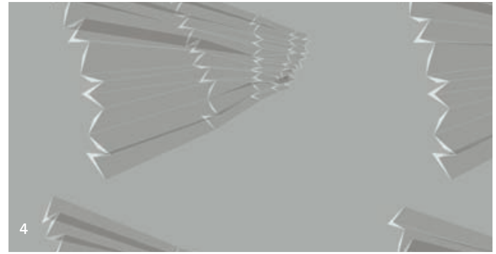
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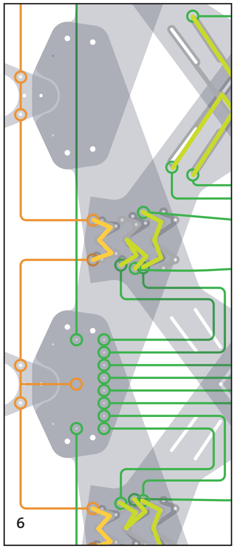
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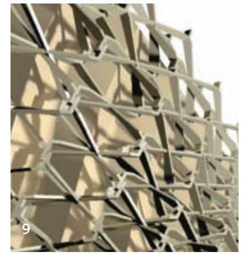
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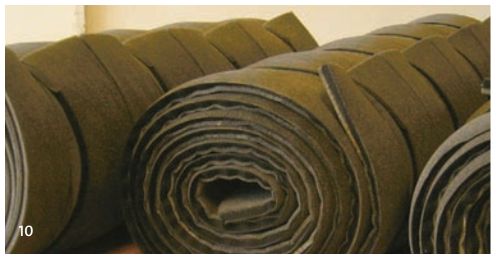
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SG1 Structural Rack Component

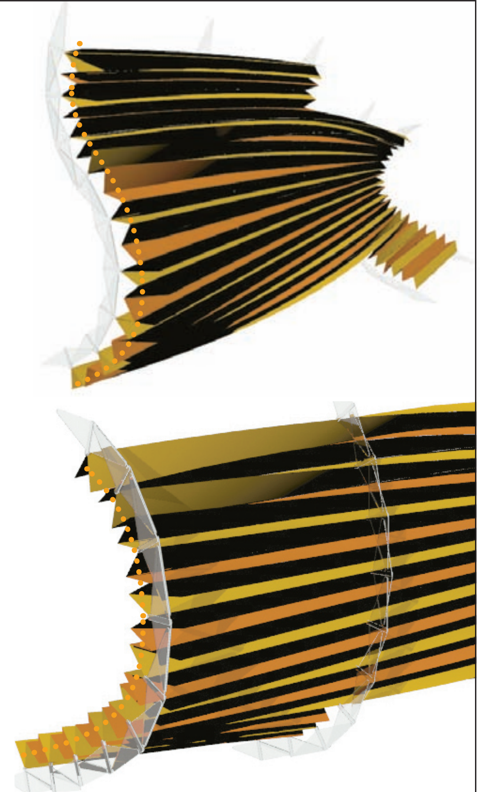
The SplineGraft structural rack enables a manual reconfiguration of the panel cross-section, ranging from convex, to completely vertical and concave configurations, or a combination of these. A modular principle allows each rack to be re-set into any configuration, through the angle between each set of two components. It also allows for a rational fabrication and production of each unit, and integrates the control circuitry for the kinetic performance. The specific shape of the structural rack components were developed though iterations of formal studies. The actuating mechanisms integral to each structural component sets the neutral position of the ribs of the foam panel. In order to avoid extreme deformation between a concave and convex configuration, the structural components must keep the distance of each rib constant over the transition between configurations, defining the first constraint for the development of the component shape. The overlap between each unit providing space for the electrical conduits to ensure the transfer of power to each actuating mechanism is the second constraint. The structural performance of the rack depends on the overlap, the structural

Generations of structural rack development

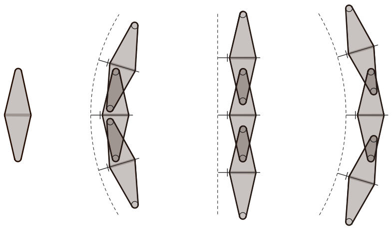
The design for each generation is tested in the convex, neutral/vertical and concave configuration. Adjacent components are directly next to each other. Semi-adjacent components have one component between them. The racks are planar, with adjacent (and sometimes semi-adjacent) components overlapping each other.

Image 1 shows the location of the constant distance line in the pleated panel. **Image 2** shows the iterations of component design.

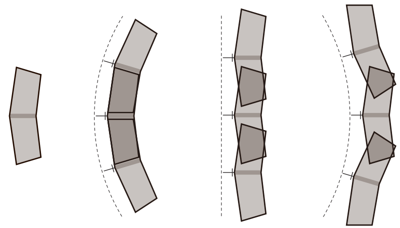
Generation 1 sets up the basic principle for the rack, including tests in digital models for constant distance measured in the center of the the folded panel. Each component is symmetrical in two axes. The overlapping parts between each unit is not enough for structural purposes nor connectors for electrical conduits. Overlap is maximized in the convex configuration of **Generation 2**, but not optimized in the other configurations, and design looks too bulky. In **Generation 3** the front and back side angles of each component are formed by the adjecent component in either of the extreme configurations, but the convext and neutral configurations have overlaps between components not adjecent, which demands a triple layer rack. **Generation 4** also need triple layers, but have more slender form and a continuous line connecting semi-adjacent components. **Generation 5** in similar, but avoids triple overlap in neutral and concave configurations. In **Generation 6** triple overlap is completely avoided, but the form is very bulky. **In Generation 7** the triple layer is avoided almost completely, but a new connection between semi-adjacent components enables a truss-like structural principle, in which greater structural depth is achieved in the neutral and concave configurations. **Generation 8** further explores the semi-adjacent connections, is very slender, but also too extensive in depth. In the final **Generation 9**, the semi-adjacent conenctions remain at moderate depth. This is the final design for the overall form.



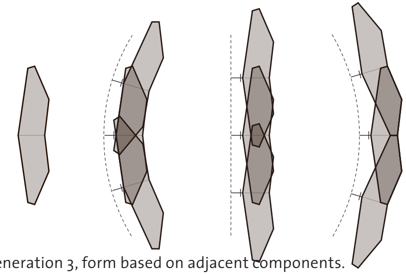
1. Line of constant distance in panel.



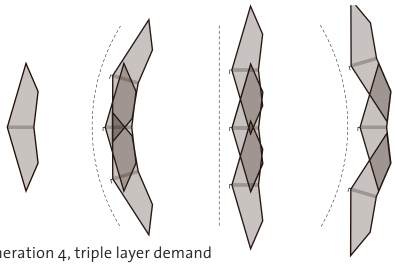
2a generation 1, initial set-up



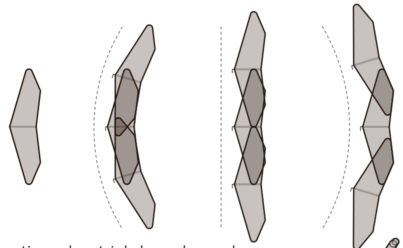
2b generation 2, convex configuration overlap maximized.



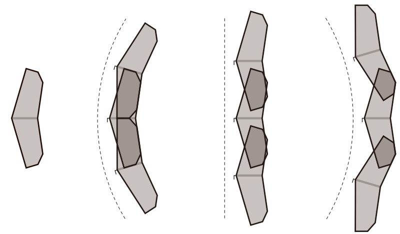
2c generation 3, form based on adjacent components.



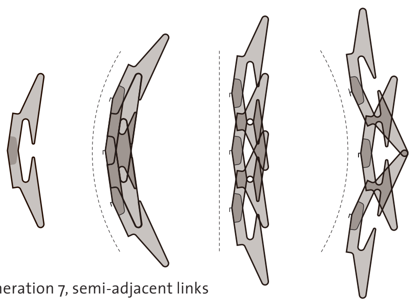
2d generation 4, triple layer demand



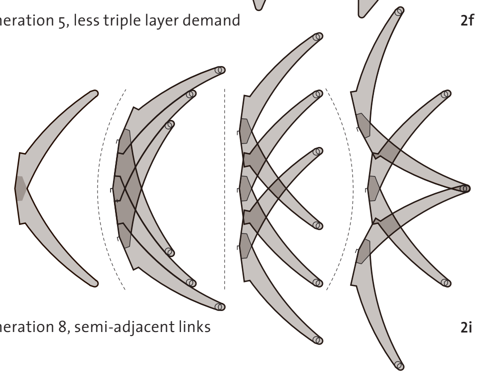
2e generation 5, less triple layer demand



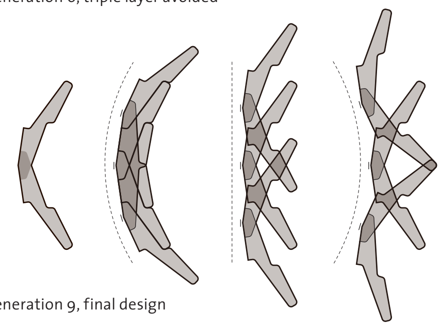
2f generation 6, triple layer avoided



2g generation 7, semi-adjacent links



2h generation 8, semi-adjacent links

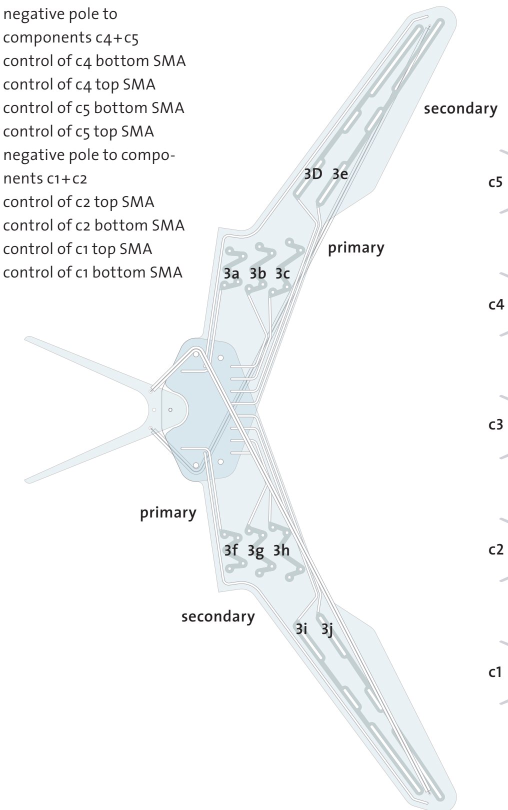


2i generation 9, final design

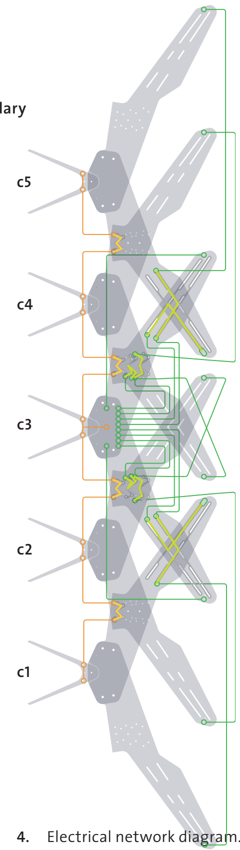
depth of the combined components and the design of the specific components, collectively becoming the third constraint. Once the final form of the rack component was defined, the integration of the electrical system was considered, based on the necessary number of conduits. The capacity for re-configuration of the rack is based on the angles between each individual component, with automatic conductive link through primary and secondary

The **image 4** diagram shows a topological overview over the electrical network overlayered the structural rack. The central component c3 includes the circuitry controlling the Shape Memory Alloy (SMA) actuators off all five components through separate power lines. Each component carries 2 SMAs for a total of 10, connected via the structural/conductive joints shown in **image 3**. The activated SMAs pull the pleated panel up or down as shown in **image 5**, inducing deformation through compression (**5a**) or expansion (**5b**). The structural/conductive joints are fabricated through etching of nickel brass plates, and enables conductive joints through the structural bolts through any of five connected holes as shown in **image 6**. **Image 7** shows the five alternate configurations through the angle between each two adjacent components, enabled by the five alternate holes of the primary structural/conductive joint and the secondary sliding joint. The secondary joints are connected to the semi-adjacent component, creating a deeper truss and allowing conductive links directly from the central component (**c3**) and the outermost components (**c1** and **c5**). When all components of a rack have the same angle, a continuous form is achieved as in **image 8**. **Image 9** shows transition between extreme convex (**9a**) to extreme concave (**9c**) through a middle rack with shifting configuration (**9b**). Each of these racks would be controlled from its central component.

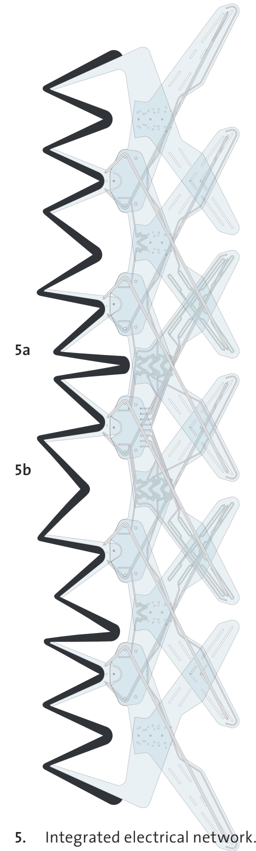
3a negative pole to components c4+c5
3b control of c4 bottom SMA
3c control of c4 top SMA
3D control of c5 bottom SMA
3e control of c5 top SMA
3f negative pole to components c1+c2
3g control of c2 top SMA
3h control of c2 bottom SMA
3i control of c1 top SMA
3j control of c1 bottom SMA



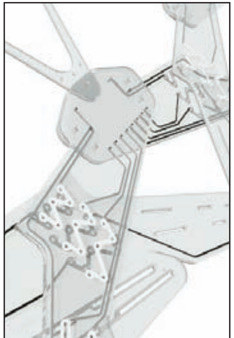
3. Primary and secondary structural/conductive joints.



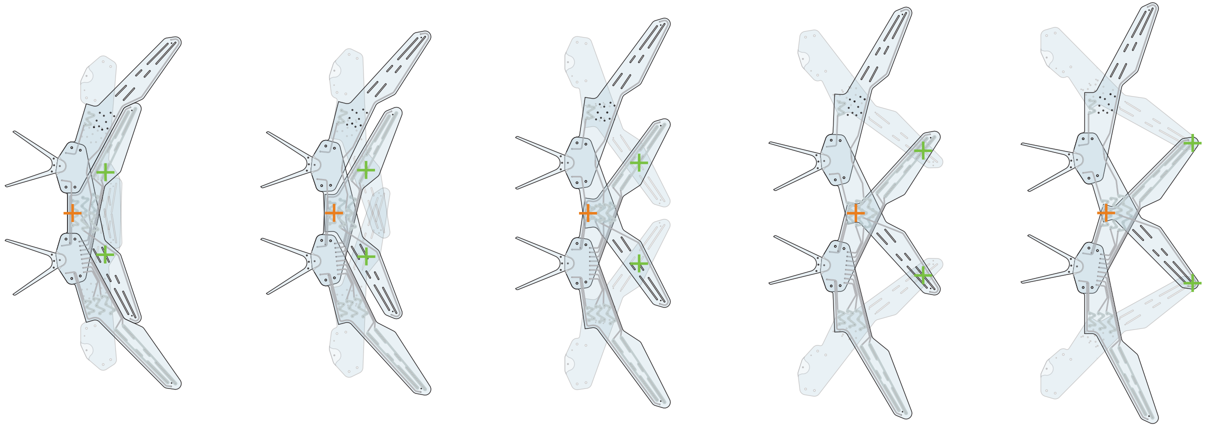
4. Electrical network diagram.



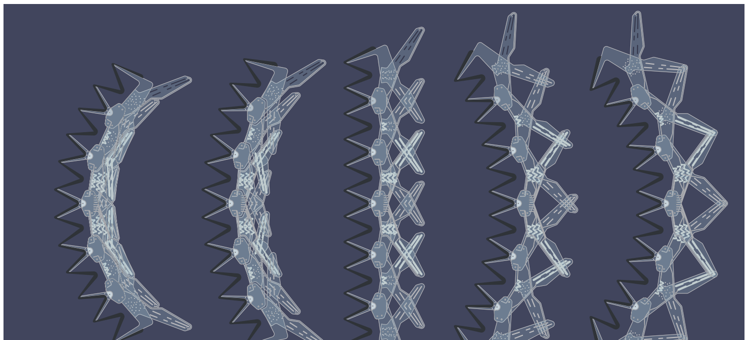
5. Integrated electrical network.



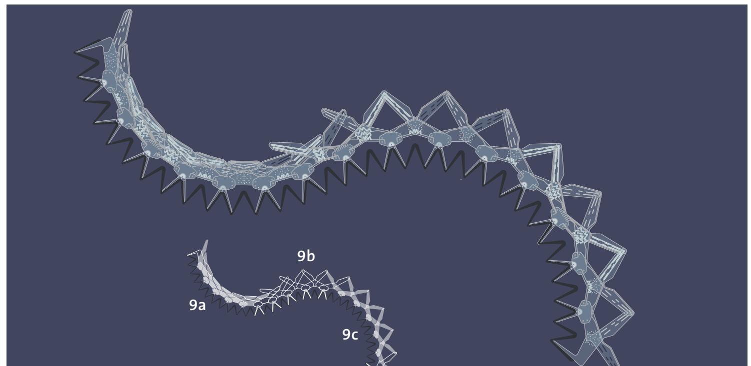
6. Rack joints component c3.



7. The five different types of primary (orange) and secondary (green) joints between components, enabling the convex to concave rack configuration.



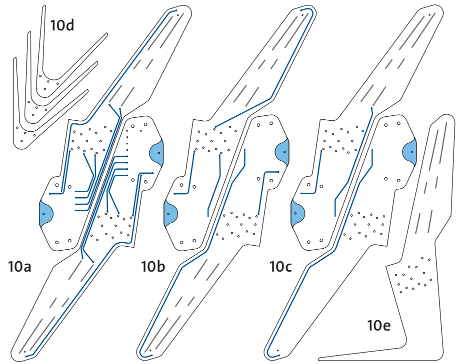
8. The five variants of structural rack configuration, from extreme convex to extreme concave.



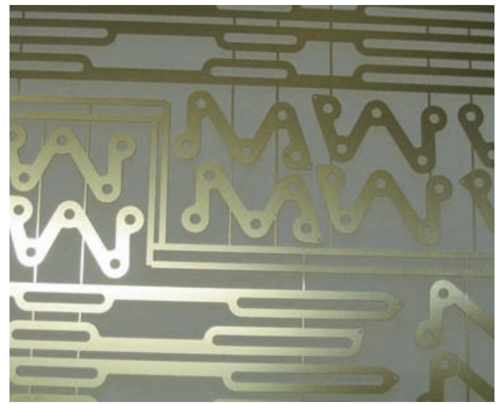
9. Composite racks in set of three, allowing smooth transition from convex to concave.

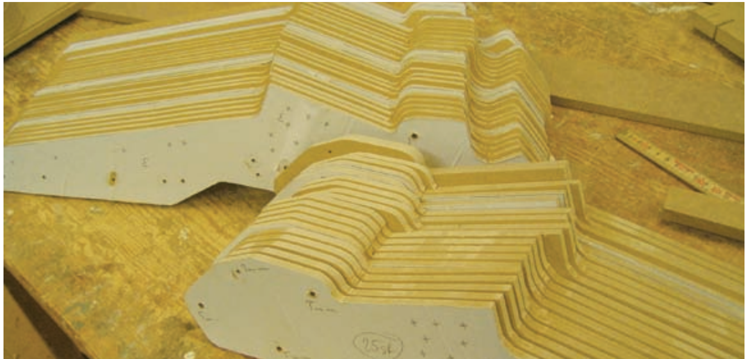
structural / conductive joints regardless of the chosen position. The structural and operative modularity of the rack on a component level is based on five units, with the central component being the control unit, which is linked to its adjacent and semi-adjacent components through integrated wiring. Each rack of five units communicates with all other racks via radio. The fabrication modularity, however, is based on the part of the structural component, each unit consisting of two mirrored parts, an actuating clutch and the necessary bolts to assemble them (**image 10**). The overall form of the structural component is identical, but the integration of the electrical wiring and conductive joints make them customized. The respective top and bottom components are identical (but upside-down in the rack), which allows for repetition in fabrication and production. For the ***fabrication*** ↓ [P.28] of the final SplineGraft composite physical prototype, cnc-milling was utilized. The repetitive nature of the rack would allow other techniques to be considered for ***production*** ↓ [P.30] purposes, such as different forms of casting, but these possibilities have not been explored. The integration of the structural, conductive and performative modular aspects in the physical prototype construes a composite testing ground, in which all these aspects co-exist. The fabrication principles are primarily tested in the design process, but integration into the composite prototype allows the testing each separate aspect in relation to the others. The final assembly is performative not only in the planned kinetic behavioral sense, but also as a structural / ornamental entity. While the performance of the panel was the primary focus of the design development, the parallel design of its necessary structure achieved formal qualities in itself.

The mirroring of top and bottom components of the structural rack limits the fabrication patterns for the structural rack to be limited to 6 separate profiles as shown in **image 10**. The racks is cnc-milled out of 6 mm clear acrylic plastic, with black lines indicating outlines, dark gray lines are paths for 3 mm routers cutting through the material, dark blue lines are paths for 2 mm routers cutting to 2 mm depth (for cable inset), light blue surface indicates parts milled down 2.5 mm (for actuator clutch). **10a** makes up the **c3** control component, **10b** is the **c2** and **c4** components, and **10c** the c1 and **c5** components. **10d** are variants of actuating clutches, accommodating for minute differences in the distance between the pleats, and **10e** is the end component, which also holds the static and of the pleated panel. **Image 11** shows the nickel brass conducting plates in their supporting scaffolding after etching, later to be attached aligned to the structural / conductive joints. The first physical prototyping was performed manually in 6 mm MDF, including the structural joints but not the paths for wiring, making all components identical as in **image 12**. The structural capacity of the racks was explored as well as the mechanic deformation of connected actuating clutches, shown in **image 13**. The final 6 mm acrylic components were produced industrially, equipped with wiring and conductive plates (**image 14**), and assembled two by two into the five components of each rack (**image 15**). **Image 16** shows the composite physical prototype with five racks with attached pleated polyurethane panel.

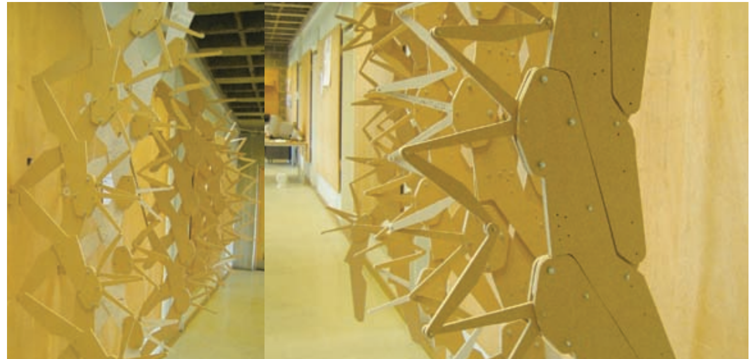


10 Fabrication patterns for structural rack.





12 Manually fabricated MDF components for physical prototyping.



13 Structural racks prototyped in MDF for configuration and mechanical performance tests.

14 Structural components fabricated through cnc-milling.

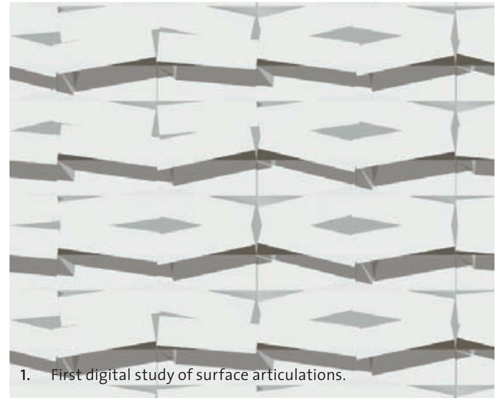
15 Two-part structural components with integrated conductors.

16 Composite physical prototype.

SG2 SplineGraft Performance

The SplineGraft starting point in an interest in the capacities of shape memory alloys, suggested a (the deformation of a particular parcel or area of the surface) in order to achieve a certain input from their light sensors. Each part of the surface is thus 'learning' how to modulate its shape in order to receive as much light as possible. Surface control is achieved through SMA actuators integrated with a steel framework and rubber springs.

The notion of the spline provided an early potential answer to the issues of deformation. The con-tem-porary use of the concept is primarily associated with geometrical software, where the spline is a mathematical interpolation of points. An early example is the *Bezier curve*, first invented in 1959 by Paul de Casteljau, but published by Pierre Étienne Bézier in 1962 as part of his work with automobile design. Later, the *Non Uniform Rational Basis Spline*, or NURBS, was defined as a generalization of the Bezier curve. The NURBS geometries have been frequently used in architecture during the past decade or so, but its origin can be traced to analogue means of approximating curves within the automotive, aircraft and boat industries. Originating from how the keel and bulkheads were produced in the shipyard, the spline became the draftsman's tool based on an elastic material deformed by control points, or weights. This analogue contraption allowed for material computation for estimating the most efficient curvature for ship hulls or aircraft fuselage. The controlled analogue deformations of similar principles were also used in early aircraft to control banking in flight. Wing warping, patented by the Wright brothers, deformed the edges of the wings in different directions through a control system of pulleys and cables, forcing the plane to roll. The principle was replaced by ailerons as early as 1911 to avoid involuntary twisting, but this methodology is currently being reconsidered in the form of computer controlled wing morphing appropriate for improved aerodynamic control and performance at supersonic speeds and in bad weather conditions. In SplineGraft, a folded surface was chosen in which the splines were active as the fold lines, or ridges in the pleats. Simple folded paper models suggested that the fold lines could achieve necessary structural integrity if supported at regular intervals. Material model studies suggested the use of an expanded polyurethane panel, which could add material elasticity as an important constraint for deformation. The spline effect could be achieved here either through cutting a profile into a solid panel, or by



1. First digital study of surface articulations.

2. The spline as draftsman´s tool.

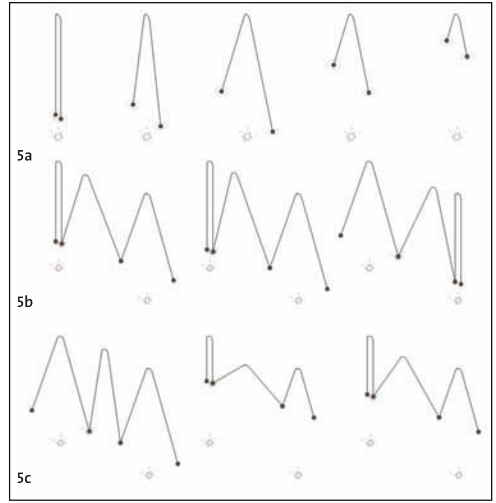
3. Shape Modulator, the first SplineGraft prototype.

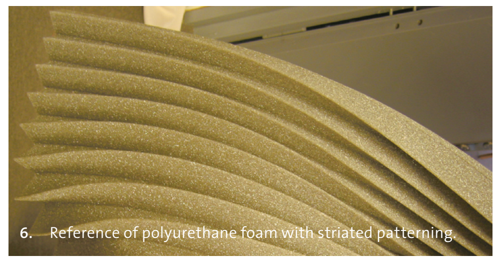
4. Shape Modulator, the first SplineGraft prototype.

Image 1 shows the first study of surface articulations as fixed units that could be rotated, affecting its neighbours through a link. In **image 2** the idea of the spline for surface articulation and deformation is introduced. **Images 3+4** shows the Shape Modulator, a light sensitive prototype that first explored the capacity of Shape Memory Alloys and their control systems, in this case responsive to light.

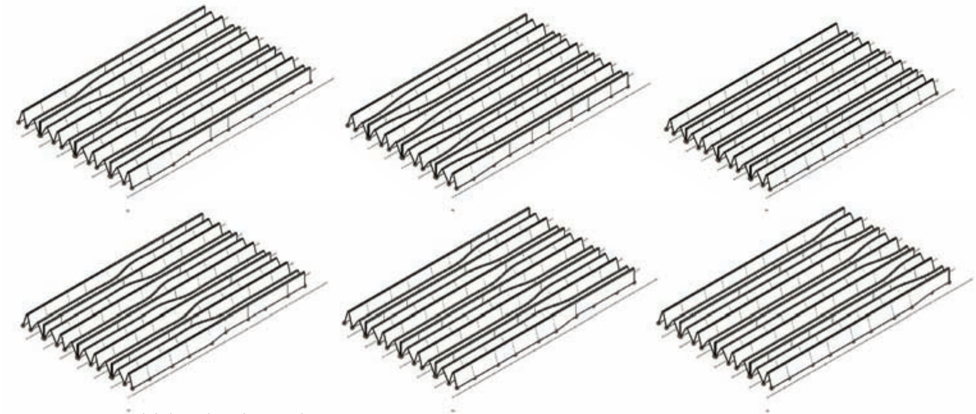
folding a thinner sheet. The sound dampening qualities of the material also provided a potential secondary acoustic performance quality. Parts of the geometry could thereby be controlled, with the remaining parts of the folds being interpolated in a spline-like fashion. Parametric geometries in GenerativeComponents, based on controlling clutches with adjustable angles defined by a set of variables, were assembled in a matrix, with surfaces lofted in between. Simulations of different individual states could be tested by feeding the model data from excel spreadsheets, with the resulting deformation of material and emerging patterns. The dynamic performance could not be explored for its experiential effect, since it would require a large amount of individual frames not possible to generate in real-time in the parametric package. Parallel digital model studies of the different states were created as NURBS surfaces, developing a non-deformed folded panel, and potential deformations at different locations across the surface. In this case, sections of the fold were controlled, with interpolated surfaces in between. The angle of the front end of every second fold was controlled in this way, with the fold in between reacting to the deformation. This principle forced the controlled fold to have an un-deformed fold line (being the centre of the angle differentiation), while the reacting fold achieved great variation. These models also suggested the integration of another deformation, leaving the flat folded panel in favor of a curvature of the overall section. The fold lines follow the curvature in a smooth way, with its striations emphasizing the change of section. The possibility of changing the overall panel form allows SplineGraft to be contextualized to specific spatial dimensions, or to add an articulated dimension to a more conventional space. The section was studied from a convex to a concave configuration. Care was taken to ensure that the folds of the panel remained at an equal distance regardless of a convex or concave position of the configuration. While the overall sectional curvature follows a radius, the equidistance of the folds is measured in the front of the panel, making the distance shift at

Image 5 shows the base geometry in the parametric model. **5a** shows one control clutch with change in angle and panel depth. **5b** shows two control clutches at each end, linked by a mediating clutch, with changes in angle. **5c** shows same set-up with changes in angle and depth. **Image 6** shows a reference panel in polyurethane foam, providing the spline mediating geometry. **Image 7** shows parametric surface models based on the **image 5** geometry, in which every second ridge is based on the control clutch (including both ridges at the ends), while the linking ridges are mediating the changes in angle. The deforming effect of the asymmetrical configuration can be seen clearly. **Image 8** shows renderings from different instances in time, with a ripple effect across the panel. The over layering of these instances in **image 9**, clearly shows the fixed location of the ridge of the control clutch, but great deformation of the ridge of the mediating clutch.

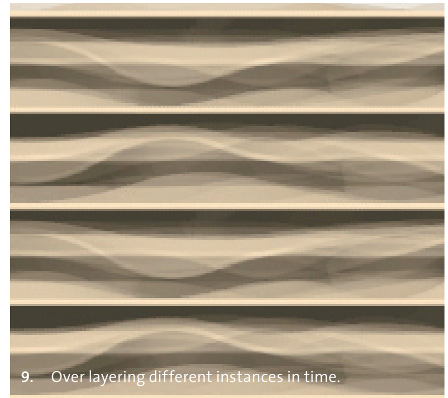




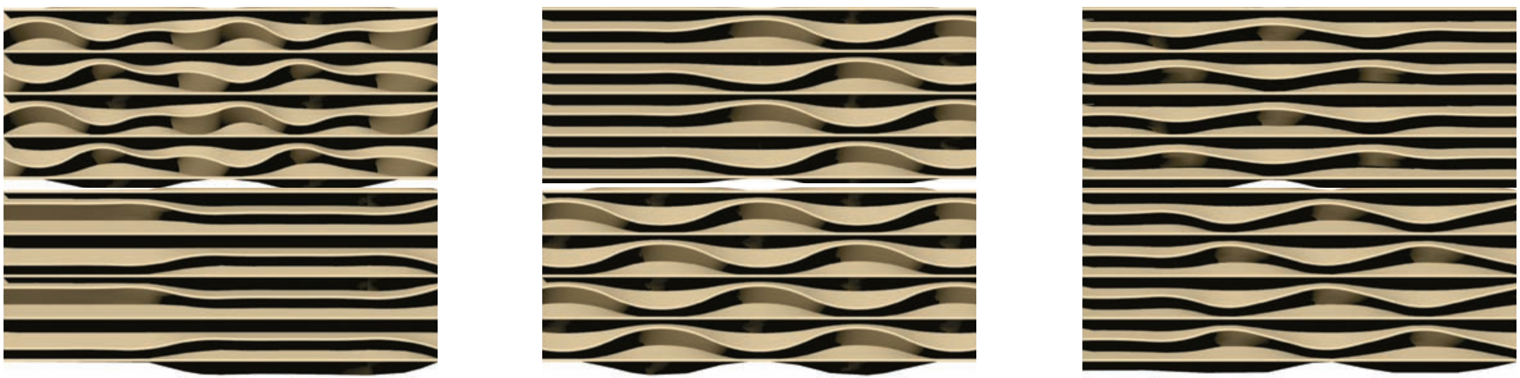
6. Reference of polyurethane foam with striated patterning.



7. Parametric models based on the initial geometry.

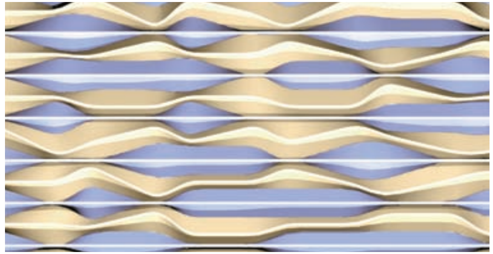


9. Over layering different instances in time.



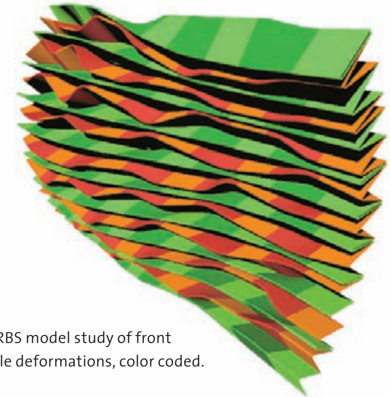
8. Renders from the parametric model, showing different instances in time.

the back end of the folds. The necessary expansion or contraction of material, depending of the change of overall curvature, would be taken up by the folds and material elasticity, in the same way as its real-time kinetic behavior. The fold lines which disperse horizontally across its surface operate as splines of a low degree in its neutral position. The local points of dynamic change during operation inform the surface, adding complexity to the curvature and conceptually shift the panel to a higher resolution. The changes of the overall form also required a primary structure to hold the folded panel. Initially, a series of fixed form frames, that would change from the convex, to planar to concave, were considered. This strategy was abandoned, in favour of a modular structural rack able to carry the load of the panel and its actuating mechanisms. In order for the equidistance of the folded panel striation to remain as uniform as possible, the supporting structural rack had to change its modulation depending on the concave/convex configuration. This required a prolonged study of its performance presented in the ***SG1 design loop*** ← [P.58]. The first version of the dynamic deformation, the **v1** flexible angle actuating clutch, depended on the change of the angle of the visible ridge in the panel. Since the **v1** principle left half of the ridges of the panel in their original state, a second version was considered. The **v2** fixed angle actuating clutch used a clutch with a fixed

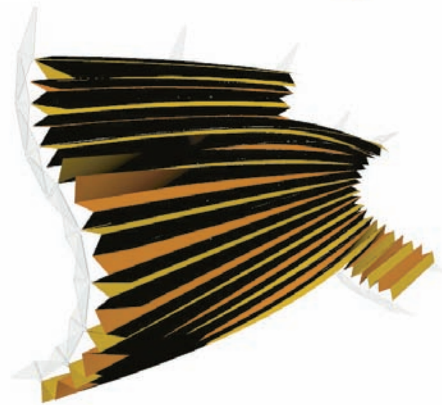


10. NURBS model study of front angle deformations, flat panel.

All images show digital NURBS surface model studies of dynamic (responsive) and static (based on the structural rack configuration) deformations of SplineGraft panel. **Image 10** shows the deformation of the mediating ridges, with the constant lines of the controlling ridges. **Image 11** shows the different parts of the panel. Light green indicates surfaces controlled by two controlling clutches in either end. Along the same ridge, the dark green surfaces are mediating between each coupled clutches. Every second ridge is mediating between the controlled ridges. Orange mediates between the light green directly controlled surfaces, while red mediates between the orange ones in analogue with the dark green. **Image 12+13** shows the same set-up without color coding. **Image 12** includes the dynamic deformation, while **Image 13** only shows the static deformation. Please note that the outer ends of the directly controlled ridges are not deformed and identical between **images 11 and 12** (the green ridges of **image 10**), while the outer ends of the mediating ridges (orange and red) have great deformation. **Image 14** shows the first version of the structural racks needed to achieve the static deformation and hold the actuating mechanisms for the dynamic deformations.

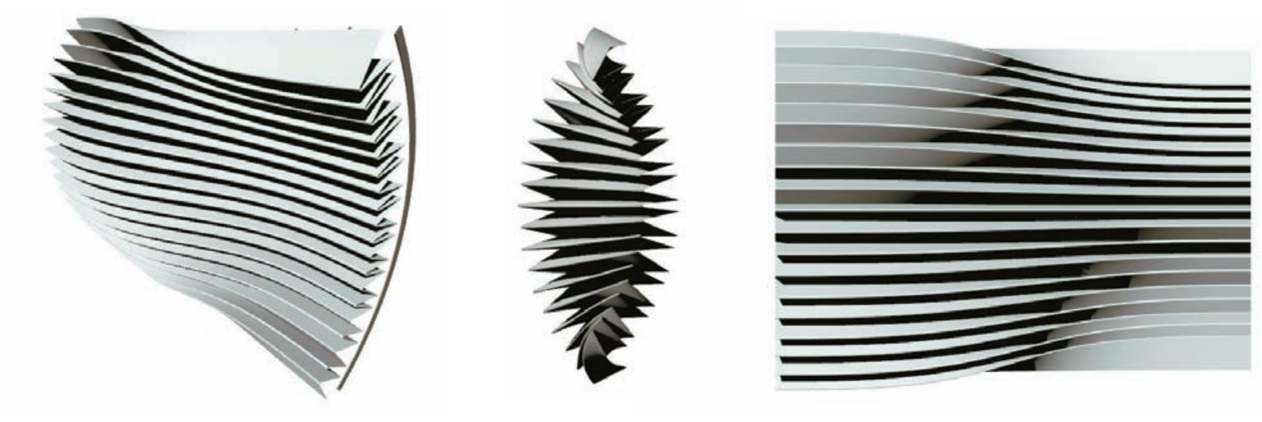


11. NURBS model study of front angle deformations, color coded.



14. NURBS model study showing first version of structural rack.

12. NURBS model study of front angle deformations, with dynamic deformation. Shown in perspective, side elevation and front elevation.

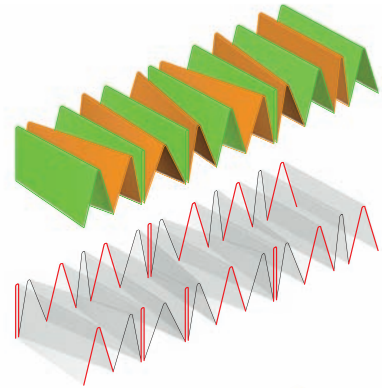


13. NURBS model study of front angle deformations, with no dynamic deformation. Shown in perspective, side elevation and front elevation.

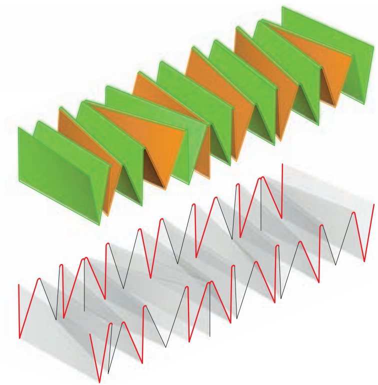
angle rotated at the base (**images 15+16**).The performance of the Shape Memory Alloy (SMA) was tested for strength and speed in a rig with mechanical parts, moved by SMA force. The rig represented a sectional part of the folded panel, with its actuating mechanisms, but with no need for the structural rack. The first studies used the v1 principle of the adjustable angle developed in the parametric models, but this proved to be lacking with respect to efficiency and issues concerning the fit to the structural rack. Instead, the v2 clutch with adjustable configuration in the base was used, a solution that ensured there would be no fixed positions in the front end. The SMAs of the rig were triggered directly by applying a current. Tests with integrated control circuits were never performed.

The kinetic behavior was explored in a series of realtime models. The first abstract 2D model, programmed in java, explored the triggering of units in a 5x5 matrix, with a resulting line elevation model showing the effect. The corresponding Processing 3D model used a simplified geometry based on the final SplineGraft configuration, with the emerging splines replaced by straight lines and polygonal surfaces. The Processing simulations enabled the integration and testing of a first generation of the controlling algorithm, which could be configured to react to different input. It made use of a clutch similar to the one developed in the mechanical rig, with reacting free moving parts linking them in section, and polygonal surfaces joining the separate actuator racks. Due to the restrictions of each medium, parallel models and prototypes were deployed to explore related issues. The static instances of the dynamic geometry were studied in detail as NURBS models developed in the Rhinoceros surface modeler. This allowed the use of the digital equivalents of splines and lofts as tools for representing the material capacities of the final physical prototype, and single exact instances of the geometries could be produced. The dynamic transformations were studied as parametric design systems in the GenerativeComponents parametric design application.

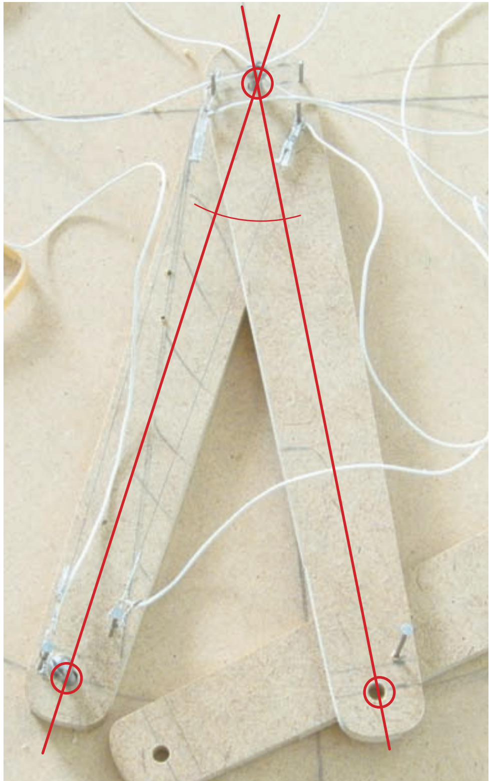
Images 15+16 show the two different versions of actuating principles (actuating clutches in red). The v1 flexible actuating clutch in **image 15** operates by shifts in the angle at the top end. While great deformation is achieved in the mediating surfaces (in orange), the ridges of the controlling clutches (in green) are never changing, but always remain parallel to the panel direction. In **image 16** the v2 fixed angle principle, the fixed clutch is rotated at the base. This makes the inner angle of the actuating groove constant, but all ridges (dividing the controlling and mediating grooves) are being deformed. **Image 17** shows the first set-up in the SMA test rig, using the v1 principle. The lever proved too small, due to the limited space provided behind the back of the panel ridge. **Image 18** shows different positions over time of tests according to the v2 principle. This set-up allowed the SMA actuators to be placed at a distance, with the rotating joint being distanced from the panel, achieving a higher pull strength.



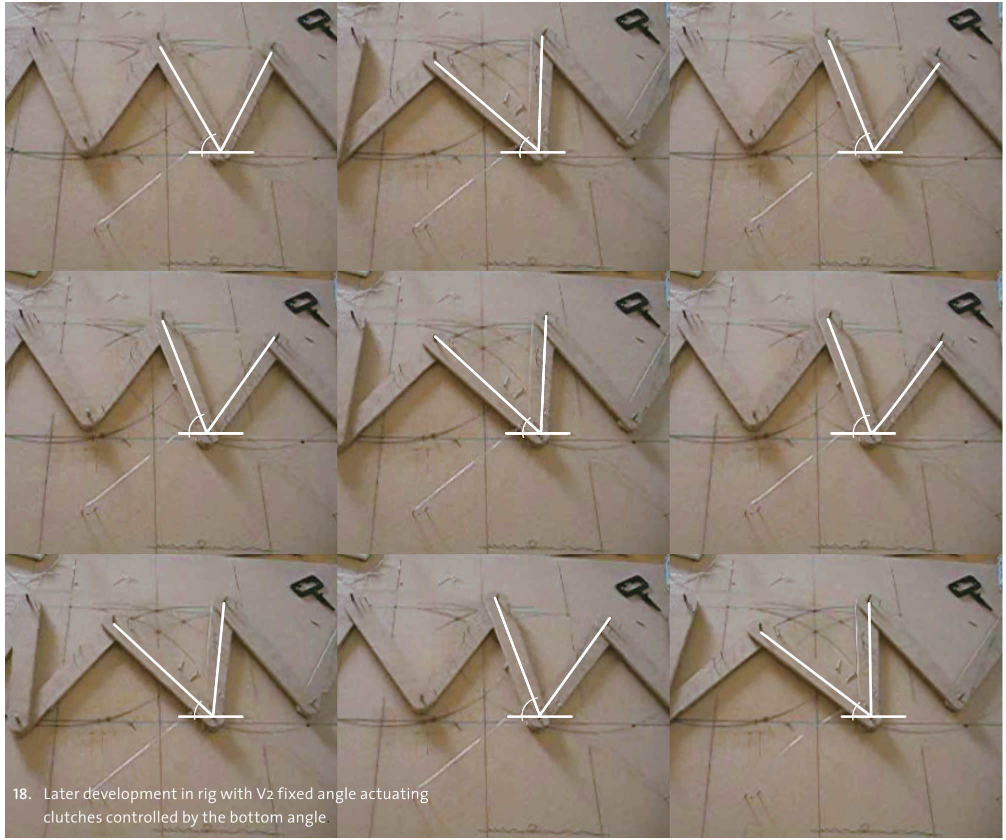
15. V1 flexible actuating clutches controlled by the top ridge angle.



16. V2 fixed angle actuating clutches controlled by the bottom angle.



17. First test in rig with flexible clutch with V1 adjustable top angle.

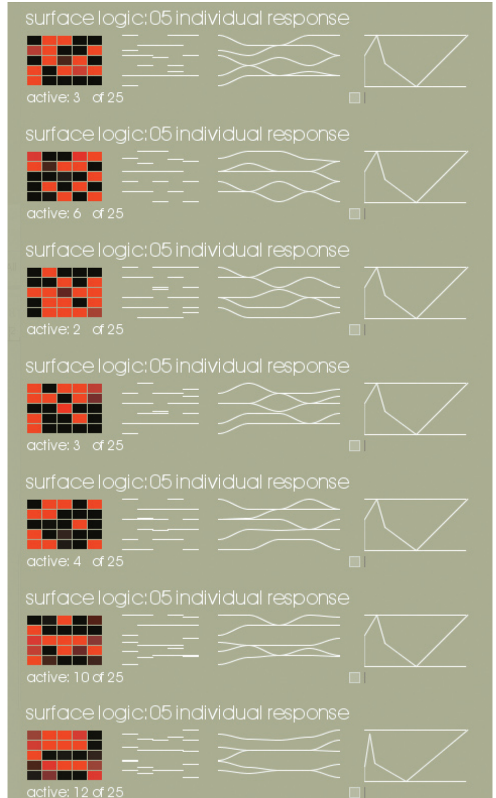


18. Later development in rig with V2 fixed angle actuating clutches controlled by the bottom angle.

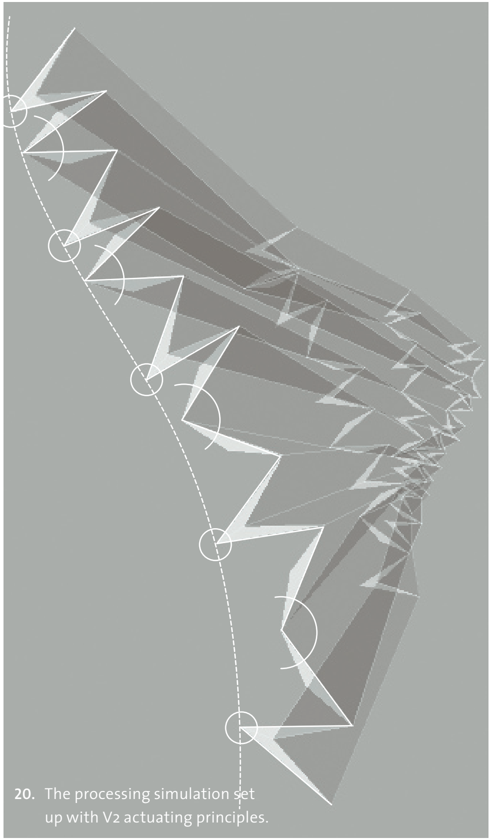
This ensured an understanding of the mechanics behind these transformations, allowing for the generation of a large number of instances in time to grasp parts of the experiential effects. The material capacities of the SMA as an actuator, and additional understanding of the associated mechanics, were studied in the mechanical rig prototype. These studies provided information concerning the performance of the SMA when integrated in the actuating mechanisms, including pulling strength and reaction speed. The design of the final version of the mechanisms was based on these experiences. The realtime models explored the behavior and to some degree the performance of the mechanisms through corresponding representations of notation and spatial effect. The models could use and test the first versions of the controlling genetic algorithm and gave the first impressions of the behavior in time, allowing adjustments to code, electronic hardware and actuating mechanisms.

The material properties of the panel set the conditions for the emerging spline striation, with its ridges and valleys, but also demanded another approach for fabrication. Early digital studies included variants of the fold lines, in which bifurcations and other patterns could be integrated; fabricated through cnc-milled custom parts. While the options of milling a striated form out of massive foam or using a folded thinner surface were both considered initially, full scale tests on the ***structural rack prototype*** ← [P.63] and early contacts with potential producers supported the latter. The base was a 20 mm polyurethane panel, which required scoring in order to be folded. No producer was able to fabricate this without the development of expensive tools, so an alternative manual strategy for manufacturing was developed. In order to create the folds, the material needed to be scored for both front and back fold lines. The front end demanded material excavation allowing a sharp fold, while the back end could be completed with only a partial cut. For the excavated parts, the foam was folded against a template, and the end partially cut with a circle saw. The partial cut could be performed with a single run in the circle saw. The scores were rein-

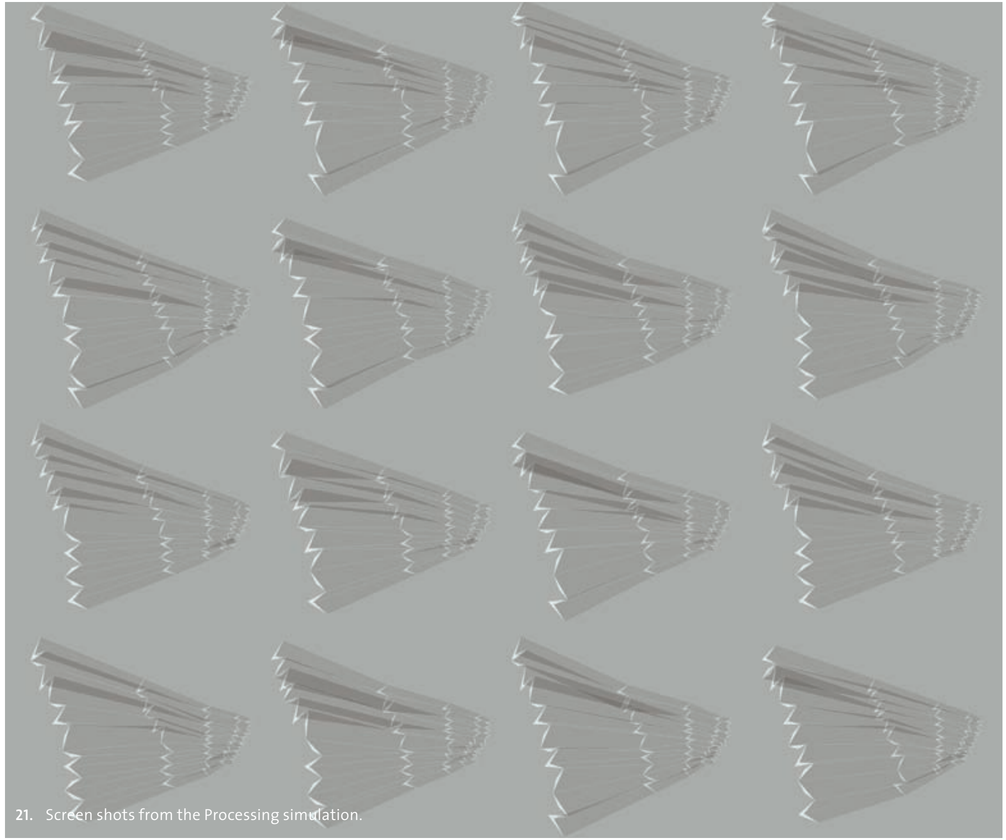
Image 19 shows seven screen captures from a java applet developed for testing the controlling genetic algorithm. The colored matrix indicates which actuating units are triggered at any given time (with a delay for the prolonged deformation effect indicated in the colors). The second diagram shows positions of each actuator, and the third simulates the spline interpolation between them. **Image 20** shows the Processing simulation of a panel with five structural racks with actuators, and five v2 actuating clutches per rack. The panel spline ridges are simplified into straight lines with polygonized surfaces. The simulation stills in **image 21** show continuous deformations of the panel. Processing allowed tests of the Genetic Algorithm with a abstract panel representation close to the final SplineGraft prototype.



19. Stills from instances in time from java behavior simulation.



20. The processing simulation set up with V2 actuating principles.

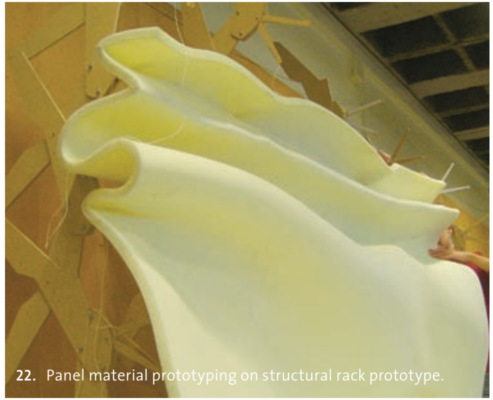


21. Screen shots from the Processing simulation.

forced with fabric. In order to allow unfolding and rolling for transportation, strips of Velcro were glued to the folding details.

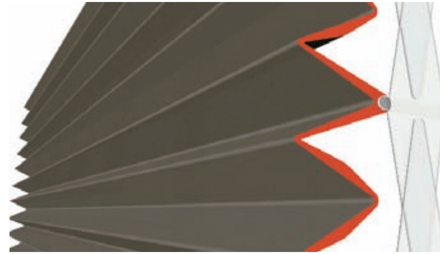
A specific SplineGraft configuration was designed for the first presentation at the *Open House* exhibition, and its exhibition space at the Zeche Zollverein in Essen. The configuration used extreme concave-to-convex transitions in the end racks, and interpolations of these in the three intermediate racks. In addition, a low wall was designed and produced at Vitra, with the purpose of allowing a visitor to peek behind the panel, as well as giving it additional mobility for later displays. While all technical systems had been tested separately, the final tests of the complete assembly had to be performed in the exhibition space itself. During these trials, technical issues regarding power demand were recognized. The power required for full panel deformation simple could not be supplied by the electronic hardware without failure due to high temperature. The panel was therefore partially assembled, leaving three structural racks free, but all racks in operation.

While the use of several development environments could be regarded as a disadvantage in the SplineGraft development, there are several benefits to this approach. Each environment has a strong focus on a particular problem that can be fully explored

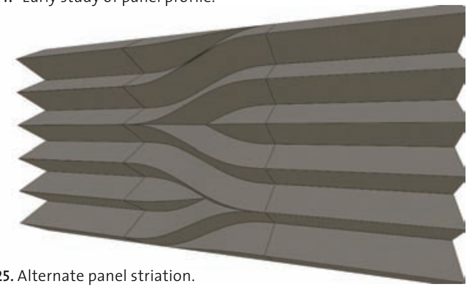


22. Panel material prototyping on structural rack prototype.

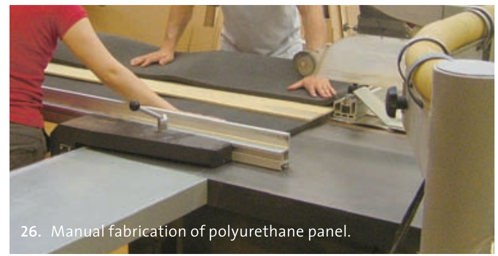
23. Panel material prototyping on structural rack prototype.



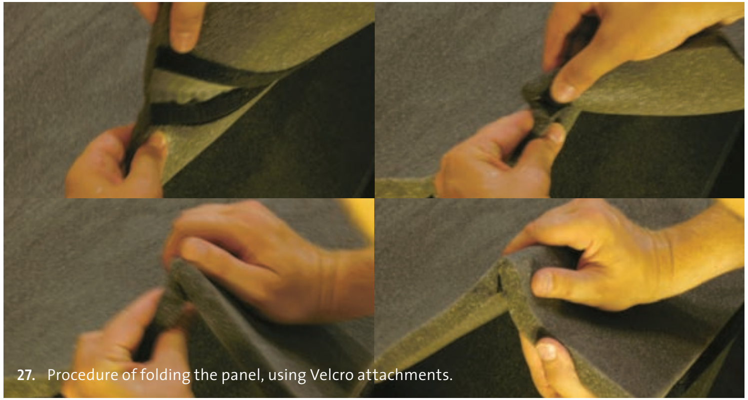
24. Early study of panel profile.



25. Alternate panel striation.



26. Manual fabrication of polyurethane panel.



27. Procedure of folding the panel, using Velcro attachments.

28. Unfolded panels rolled up for transportation.

Image 22 and **23** show lower grade foam testing the attachment to the structural rack, and the possibility of achieving the interpolating spline in the ridges of the folds. **Image 24** shows alternate more articulated profiles, which would have depended on cnc-milling of entire sheets. **Image 25** shows a bifurcating pattern which would have depended on more advanced production principles, and was therefore abandoned. The fabrication of the panel was done manually using regular workshop machines, in a step by step procedure making one score at a time as shown in **image 26**. In order to make the SplineGraft installation mobile and possible to transport, the folds were mounted with Velcro attachments that allowed them to be closed and re-opened, as shown in **image 27**. This allowed the panels to be flattened and rolled up as in **image 28**. **Image 29** shows the higher grade polyurethane acoustic foam set up in the final version of the acrylic structural rack. The close-up in **image 30** shows the Velcro attachments as well as textile reinforcements in the scored parts of the foam.

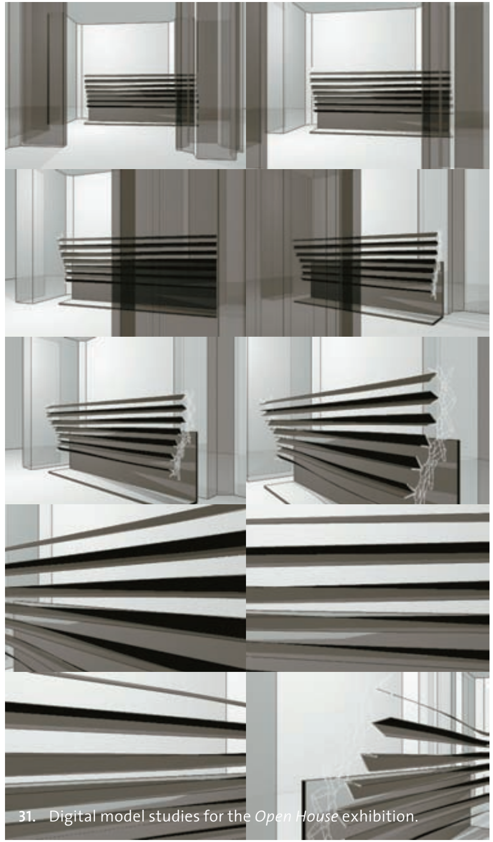
29. Panel material prototyping on final structural rack.

30. Textile reinforcement and Velcro attachments on back of panel.

using the particular characteristics of that setting, while related issues can still be identified. The change between environments requires a remediation of the material, in which additional aspects, such as structure, program or material, need to be formulated and provided. These transitions gave a natural phasing of the development, which would not have been obvious had one complete prototype been developed immediately.

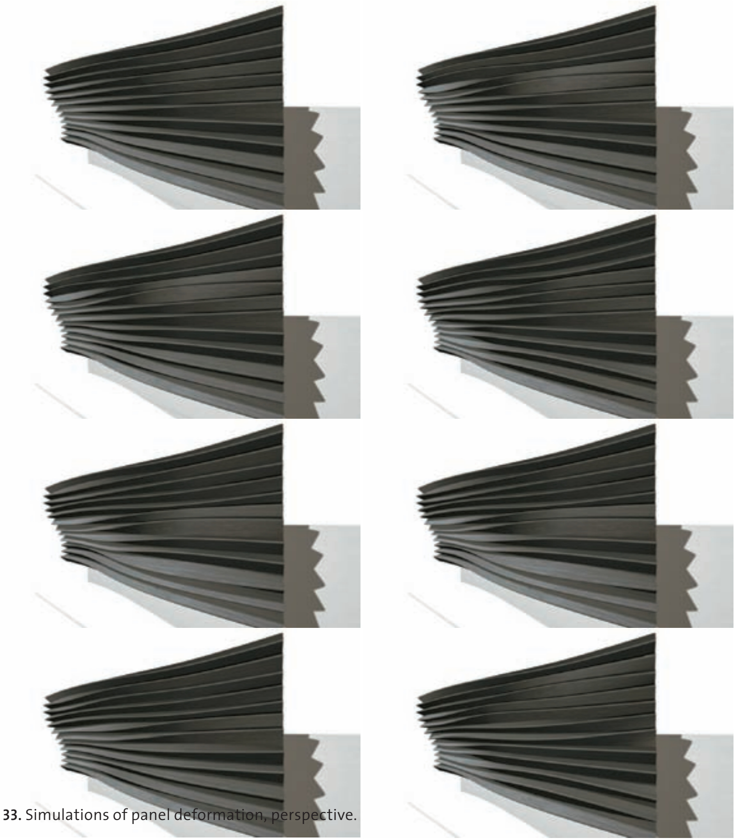
The behavior of Shape Modulator, the first SplineGraft prototype, is not very different from the phototropism of plants which attempt to grow shapes that optimize their exposure to light; when many plants grow together, similarly to the electronic cells in this prototype, they have to negotiate their shapes in relation to one another, forming ecological bounds and relations between them. The principle of ecologies of intelligent cells capable of modu-

Digital models were used to simulate and explore the potential *SplineGraft* behavior, as well as plan and design how it would be presented in the context of the *Open House* exhibition. **Image 31** show stills from a walk through animation developed to decide on the static deformation of the structural rack, the location in the space and the design of the exhibition base. Simulations of the behavior based on the v2 actuating principle set up as in the exhibition installation were done in renderings, shown in elevation in **image 32** and perspective in **image 33**. The partial installation used in the final display shows both the structural rack and parts of the panel mounted between two racks, as shown in **images 34+35**.



31. Digital model studies for the *Open House* exhibition.

32. Simulations of panel deformation, elevation close-up.



33. Simulations of panel deformation, perspective.

34. Partial SplineGraft installation at the *Open House* exhibition.

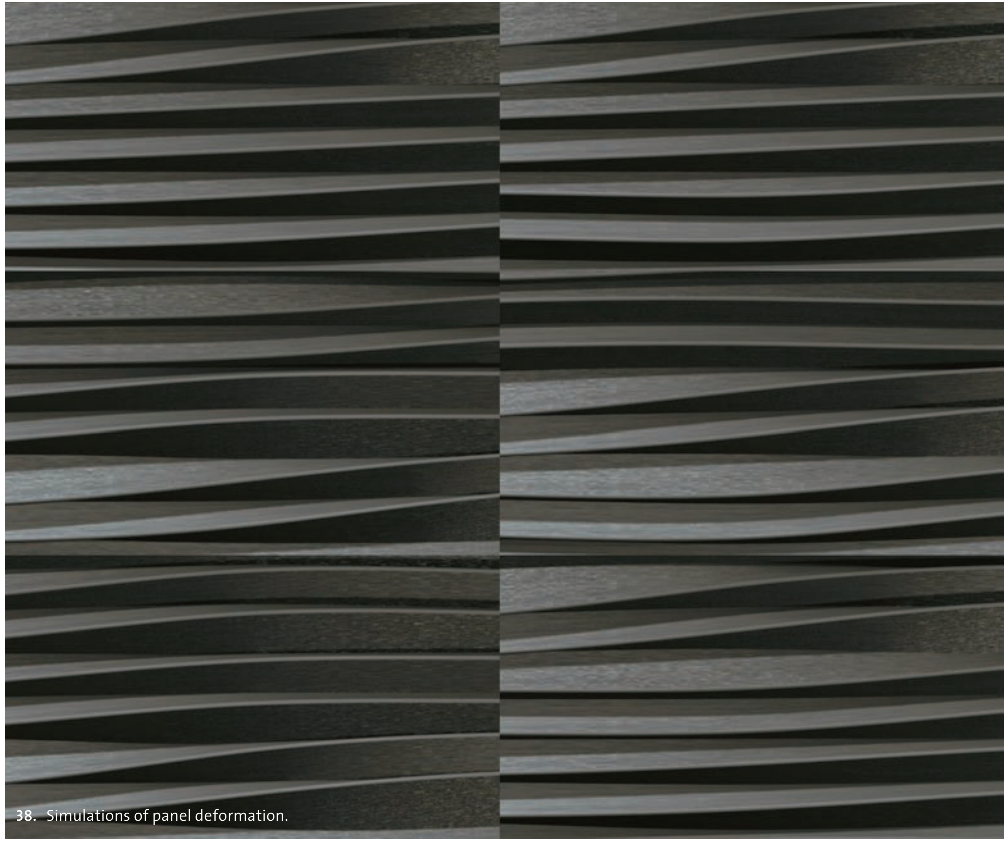
35. Author by the partial SplineGraft installation at *Open House* the exhibition.

lating environmental conditions (light, transparency, acoustic properties, air flow, etc) is an aspect that also informed the SplineGraft installation. The cells, or packets of intelligence in the sense that they are capable of making simple decisions, are able to communicate with each other and with external devices through wireless infrared in the Shape Modulator. In SplineGraft, each structural rack carries its own cell, and the communication between the racks is carried out with wireless radio. The overall behavior is further controlled by a ***genetic algorithm*** ↓ [P.35]; a computer program that simulates and compresses the slow processes of natural selection to moments of computational time, in order to evolve solutions to specific problems. The SplineGraft algorithm is in this way attempting to emit patterns of movement which stimulate occupation of the space it has been grafted into. The matching of sensor readings and motor reactions in an apparently intentional way by the SplineGraft, ***transforms architecture into a cybernetic agent involved in the making and production of space*** ↓ [P.16 | P.26 | P.40 | P.44]. In effect, this SplineGraft entity is evolving in order to become more popular among the public.

In a later presentation at the Städelschule in Frankfurt, Sanford Kwinter commented on the idea of SplineGraft as an entity, in the sense that it acquired qualities of an animal, or even a predator, in the sense that it depends on the feedback of others in order to perform, and also induces activities and interest in an audience. He saw this as an indicator of the animal world he had already suggested would replace the machine world of the past century, in which objects and systems could be allowed to be understandable in social environments, and also be part of ***new ecologies of communication*** ↓ [P.9]. As an evolving entity, Kwinter proposed that SplineGraft currently existed at an early animal stage. Other comments by external parties have indicated a strong interest in the elaborate characteristics of the structural racks, in which all technical systems are integrated and given aesthetic qualities outside of the main performance of SplineGraft as a spatial intervention. At times, these aspects of the projects have been criticized for being too elaborated on, especially when seen as a purely technical system hidden behind an architecturally articulated panel surface. The final set-up at the *Open House* exhibition further showed the fascination of the ornamented structure in itself, when SplineGraft operated as a demonstration of mechanisms and processes normally invisible. The prototype assembly here resembled the demonstration model of an advanced engine, in which all moving parts are exposed to an audience, but the actual performance, as part of a vehicle, remains in our minds. The exhibition was complemented by animated simulations of the panel deformation, as well as the partial panel between two racks, which gave enough input for the audience to experience both effect and technical performance.

36. The SplineGraft assembly with complete panel.

37. The SplineGraft assembly with partial panel.



38. Simulations of panel deformation.

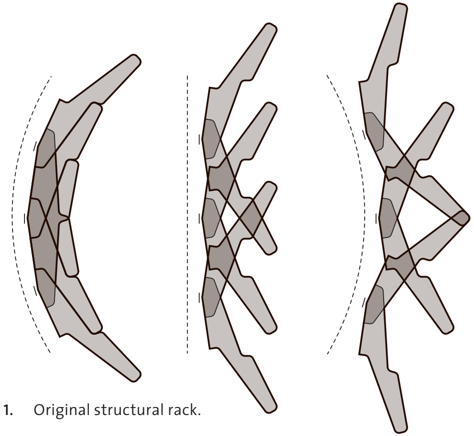
SG3 SplineGraft Refit

The SplineGraft Refit design loop considers an alternate solution to the ***SplineGraft structural rack*** ← [P.58]. The original racks are sectional and flat, requiring additional supports when mounted to a wall in order to gain stability. SplineGraft Refit aims at the development of a spatial system that acquires self-stability, needing only limited additional support. The purpose of the SplineGraft structural rack is to accommodate for various configurations of the supporting structure. While the original structural rack has a high degree of repetition in its components, the employed fabrication strategy of cnc-milling would actually allow more individual manufacturing, even when transferred into production.

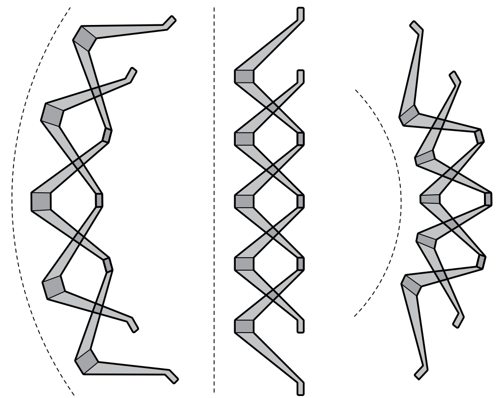
Certain aspects of the SplineGraft project were adopted as conditions.

1. The aim was to transform the vertical structural rack into a 3D-framework, in essence a space frame, with horizontal as well as vertical structural connectivity.
2. The original SplineGraft rack components are planar, with integrated milled paths for electronic control systems. The control network set the conditions for the component joints, in the sense that ***they double as conductors*** ← [P.60]. Each individual component links not only directly to its neighbor, but also indirectly to its second neighbor. The direct and indirect linkage in SplineGraft (2+2 joints connecting to 4 components) is continued and proliferated in the Refit configuration (4+4 joints, double joints connecting to 16 components), with a higher level of network integration.
3. The manufacturing method of cnc-milled planar panels would be retained, setting high limits on the design.

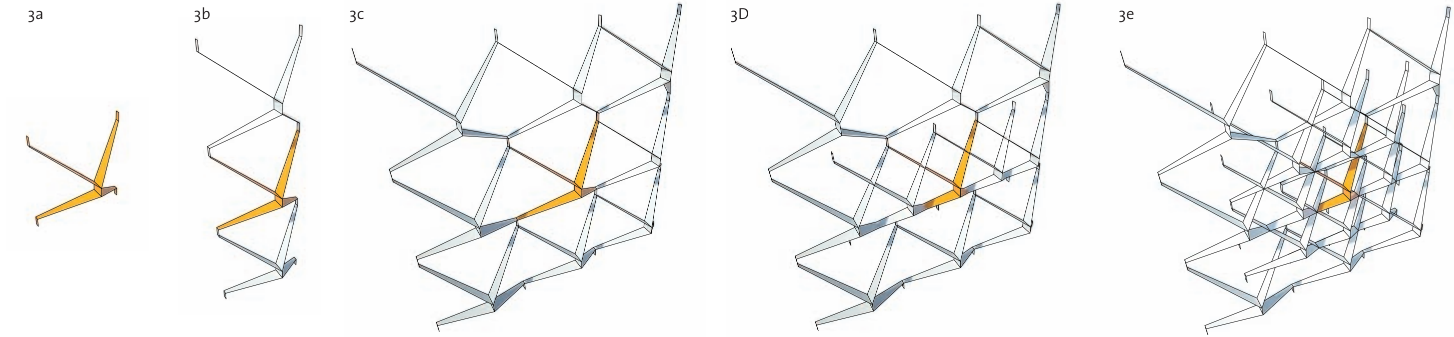
Three different configurations of the original SplineGraft structural rack is shown in **image 1**, with identical components being shifted in position. **Image 2** shows the corresponding section of SG Refit, in which the components are adapting to curvature, depending on the generation of custom parts. The sequential propagation of the SG Refit component based on the original SplineGraft principles is presented in **image 3**, showing the added horizontal connectivity. **Image 3a** shows single original component and **image 3c** shows all 8 secondary neighbors. The two horizontal direct neighbors are added in **image 3D**, and the 2 vertical in **image 3e**. The new logic of the framework allowed the definition of a new component through a re-modularization based around the intersection of direct neighboring units in an internal joint, as shown in **image 4**. The new component was then re-designed to avoid collision of parts, introducing a core unit to accommodate the internal joint, ensuring that planar elements remains after deformation of control surfaces, as shown in **image 5**.



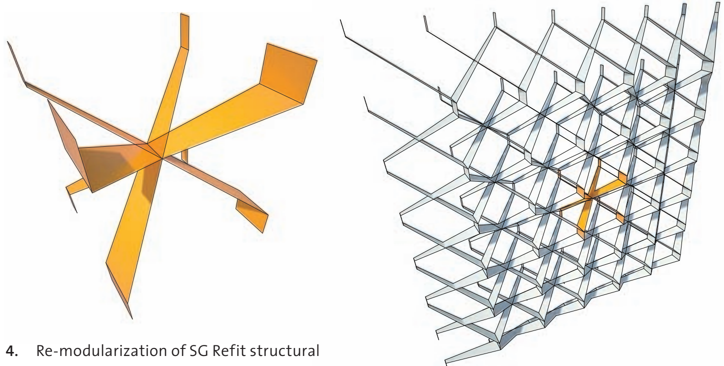
1. Original structural rack.



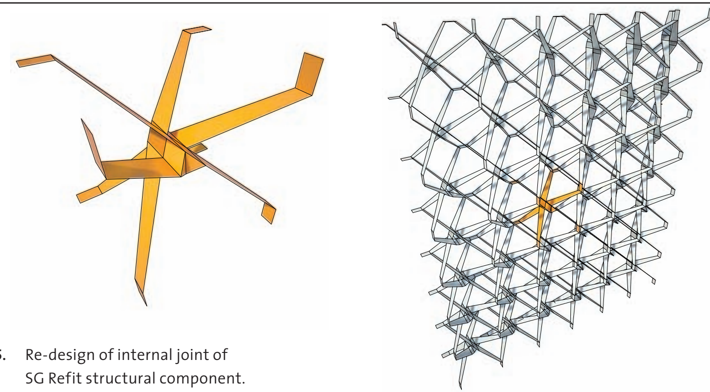
2. SG Refit structural framework.



3. Aggregation of structural component based on original structural rack.



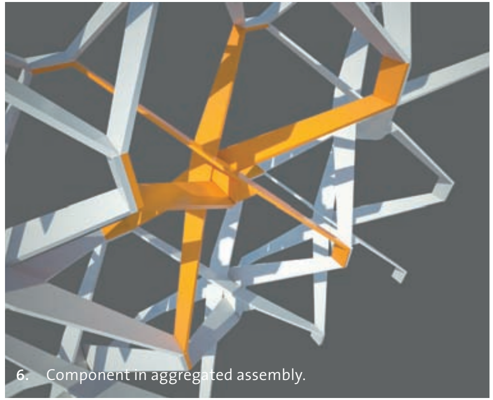
4. Re-modularization of SG Refit structural component in a full framework.



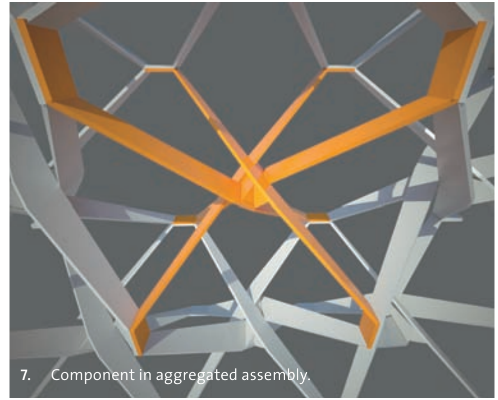
5. Re-design of internal joint of SG Refit structural component.

The development of the SplineGraft Refit structural rack is based on a free-form global control of the overall surface, and a system of components adapting to this primary form. It makes use of one of the primary strengths of the GenerativeComponents parametric design system; the adaptation of a component to local variations in a global system. In SplineGraft Refit, each structural rack unit is unique in form, as a part of the 3D-framework. Integrated ***constraints*** ↓ [P.16] ensure that each component can be fabricated from a cnc-milled planar element, with additional scores for folding. This direct relationship to fabrication allows the mass customization of parts, and a rational production of large numbers of units. The main difference between the original SplineGraft structural rack system, and the SplineGraft Refit spatial framework, lies in the potential for recombination. While the generic form of the original components allow each rack to be re-set within the convex/concave extremes, the Refit framework, with its customized components, must be manufactured for a specific overall form.

The parametric system designed in Generative Components is based on two NURBS surfaces that define the inner and outer boundary of the framework, and two grids based on the UV coordinates of each surface. The components are linked to one frame of each grid. The truss in each component,

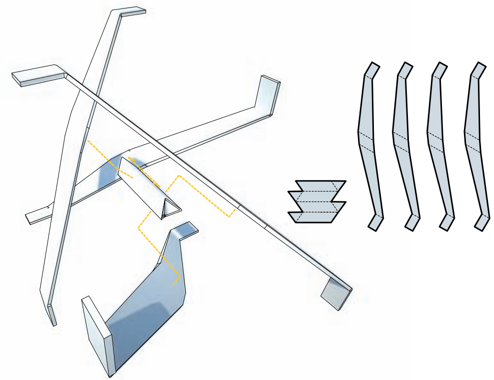


6. Component in aggregated assembly.

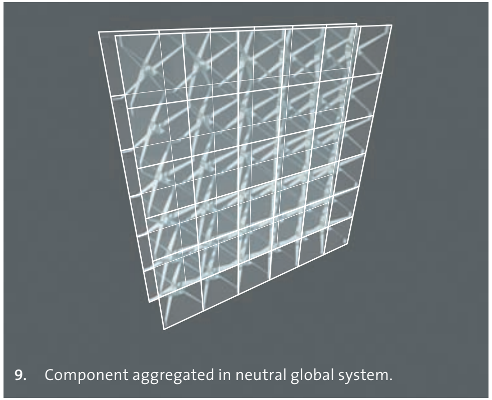


7. Component in aggregated assembly.

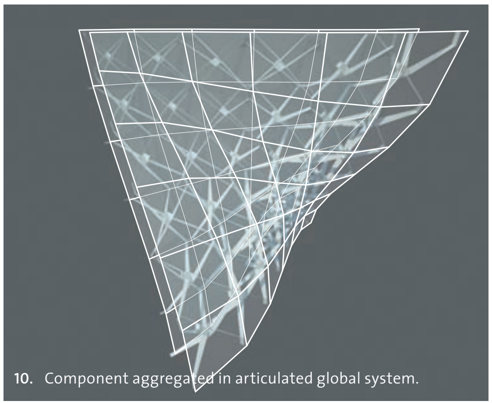
The component as inserted in an aggregated assembly is shown in **image 6** and **7**, where the vertical orientation of the component joints in the front can be distinguished from the horizontal orientation at the back. The principle of assembly around the central core unit is shown in **image 8**, including the pattern of all five parts of the component unfolded. **image 9+10** show the two control surfaces that can be manipulated globally for overall form, through which each component is deformed locally through the transformation of the bounding box that is formed between the individual squares of the two grids. There are two types of local component deformation. In the first type, the internal joint changes its configuration depending on its local deformation, as a part of the mechanism ensuring that there is no collision between the planar elements, as shown in **image 11–14**. Please note how the order of the elements is shifted between configuration 1 in **image 11+12** and configuration 2 in **image 13+14**.



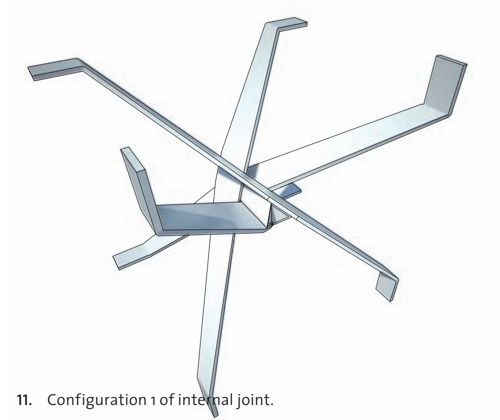
8. Assembly of component and patterns of unfolded units.



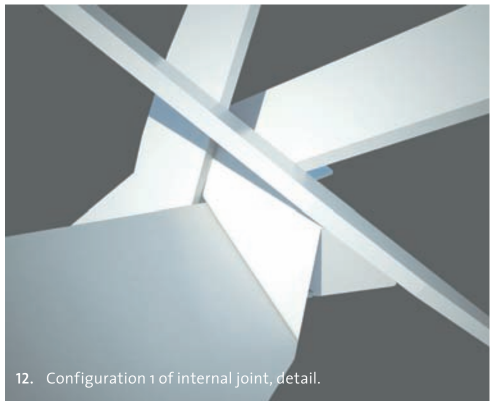
9. Component aggregated in neutral global system.



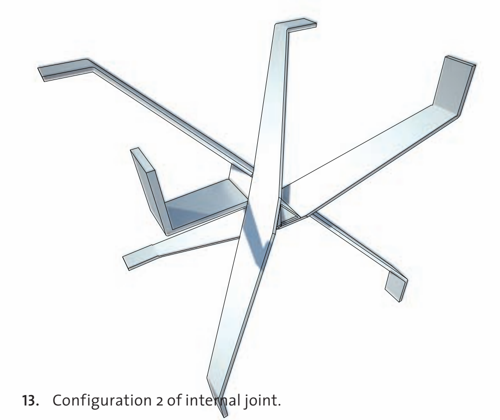
10. Component aggregated in articulated global system.



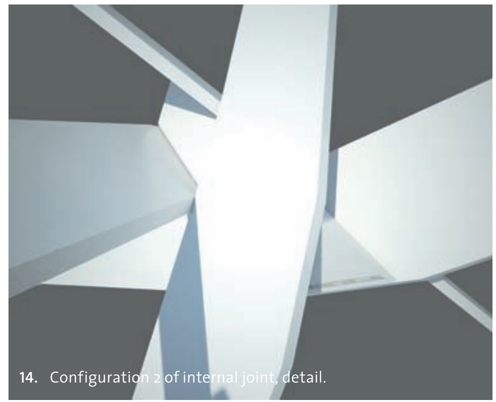
11. Configuration 1 of internal joint.



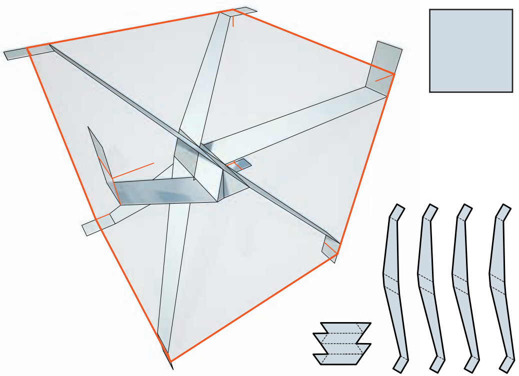
12. Configuration 1 of internal joint, detail.



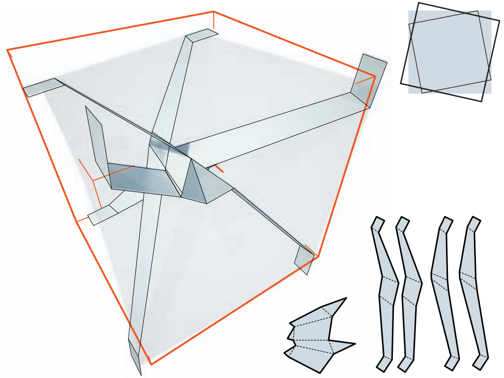
13. Configuration 2 of internal joint.



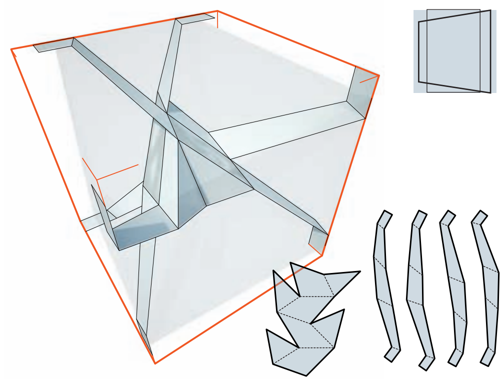
14. Configuration 2 of internal joint, detail.



15. Neutral bounding box state.



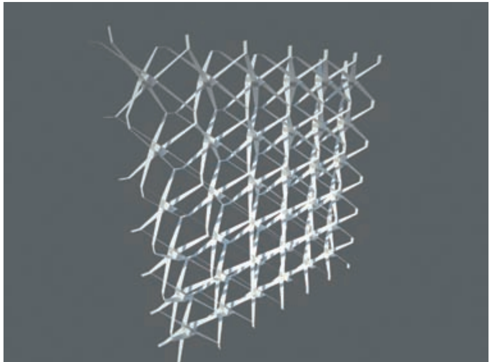
16. Bounding box deformation by rotation.

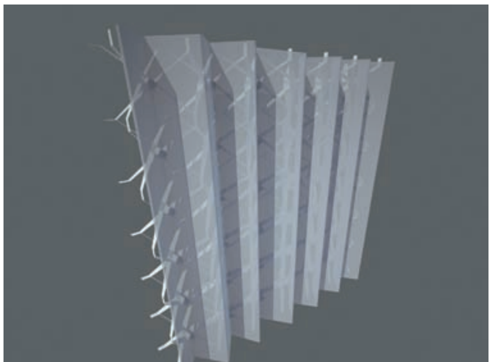


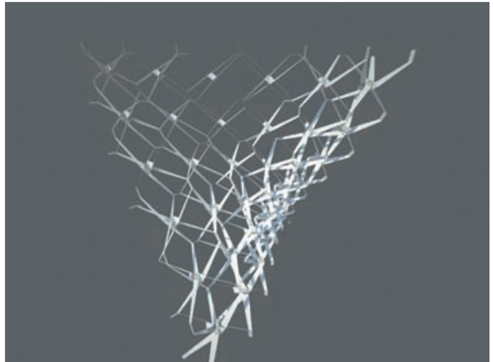
17. Bounding box deformation by tapering.

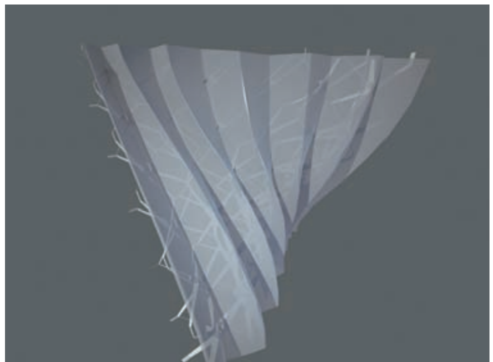
composed of planar, but folded, elements, risk collisions between its parts when deformed throughout the framework. In order to avoid this event, each component is equipped with a conditional code, which must adhere to one of two principles for its build through a ***one directional dependency*** ↓ [P.16]. The interlocking detail that is the result of this operation resembles the original SplineGraft component overlap, but operates in two directions around a core unit; a box folded from planar elements, adding additional structural stability to the framework. The geometrical principle of the Refit framework also imparts a directionality, which can be used for the future integration of the folded SplineGraft panel and its actuating mechanisms. This directionality differs between the front and the back, one being vertical and the other horizontal. The composite structure acquires the striated qualities of the original SplineGraft panel, which may allow the use of the earlier actuator principle, previously referred to as ***v1*** ← [P.70]. The development of the SplineGraft Refit design loop does not encompass the actuator mechanisms as adapted to the new structure, but recognizes a more intricate potential in the network distribution of the control system.

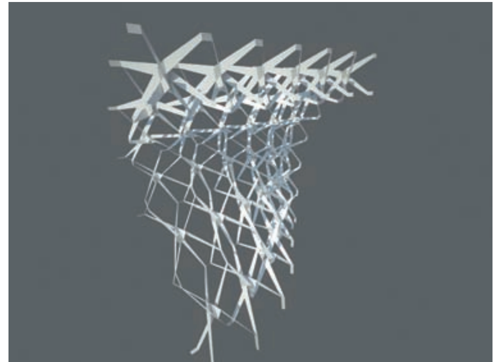
In the second type of local deformation parts of the component is locally transformed, based on the logic of a bounding box. **Images 15–17** show the component in its bounding box, a diagram of the deformation and the resulting production patterns of the sub-components. In **image 15** the bounding box is un-deformed, resulting in identical sub-components. In **image 16** the box has been deformed through rotation of front and back squares, resulting in deformation of all parts. The tapering transformation in **image 17** also requires custom parts, as well as a larger core unit. The joints in the bounding box corners are shifting positions but retain their shape, allowing the component to fit with its neighbors. **Images 18–23** present assemblies of different articulation, as well as the mounted SplineGraft panel. The examples use a vertical configuration, but the original horizontal would be possible through reversal of the component (back-to-front). **Images 18+19** show the assembly in a neutral, planar set-up. **Images 20+21** and **22+23** show two different articulates states.

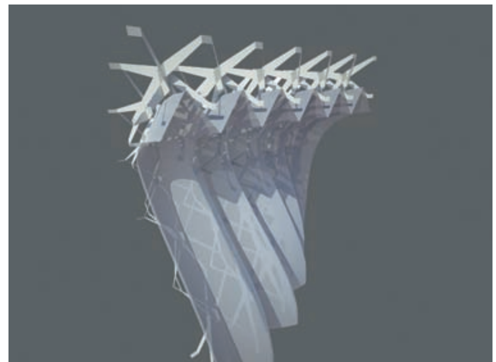

18. SG Refit framework assembly, neutral state.


19. SG Refit framework assembly, neutral state with panel.


20. SG Refit framework assembly, articulated state.


21. SG Refit framework assembly, articulated state with panel.


22. SG Refit framework assembly, articulated state.


23. SG Refit framework assembly, articulated state with panel.

Urbantoys v.2
Design Project

Servo's Urbantoys project diffuses the conventional roles of manufacturer, architect, designer and user/ consumer. The project is designed as an interface that provides tools for the design of architectural products, via a series of manipulations of a digital model. It operates on a conceptual level, and while some parts of the project are fully functional, others work on a more speculative level and suggest future modes of design, manufacture and production.

In the Urbantoys project, 'toy' connotes a digitally malleable set of geometries which are animated by the toy's user and can be assembled computationally as a three-dimensional model or produced as a physical instance. The toy's components are set in motion as a series of spatial units which are activated by the user. The assembly of digital pieces is non-sequential and proliferate into a series of models. The viewer is invited to act on a supplied catalogue of materials and infiltrate the design process. By submitting designs to and sampling designs from an online archive, the visitors' designs are made available to other potential authors. The interface also provides the possibility for the visitor to directly engage with a manufacturer by ordering a rapid prototype of the designed object.

The project was developed in two versions. *Urbantoys v.1* was first presented in 2000 as an installation at the crac exhibition at Liljevalchs Konsthall, Stockholm. A second instance was made at the N2art exhibition, where it operated fully on-line. *Urbantoys v.2* was a commission from IASPIS to Servo, who in turn ***commissioned Krets for the system development of the project*** ↓ [P.51]. The second version of the project has been presented in a number of venues, which has allowing different approaches to the way it has been contextualized.

Credits:
Urbantoys v.2 is a project by Servo. *Krets* was commissioned to develop the design system for the *Urbantoys v.2* browser and interface.

Project architect: Ulrika Karlsson
Design: Ulrika Karlsson, Marcelyn Gow

Urbantoys v.1 design team: Jonas Runberger, Daniel Norell, Nina Lorber, Ulrika Wachtmeister, Alice Dietsch, Johan Bohlin, Oskar Jonsson, John Stäck.

Urbantoys v.2 Krets design team: Jonas Runberger, Daniel Norell. Database design: Oskar Scheiwiller.

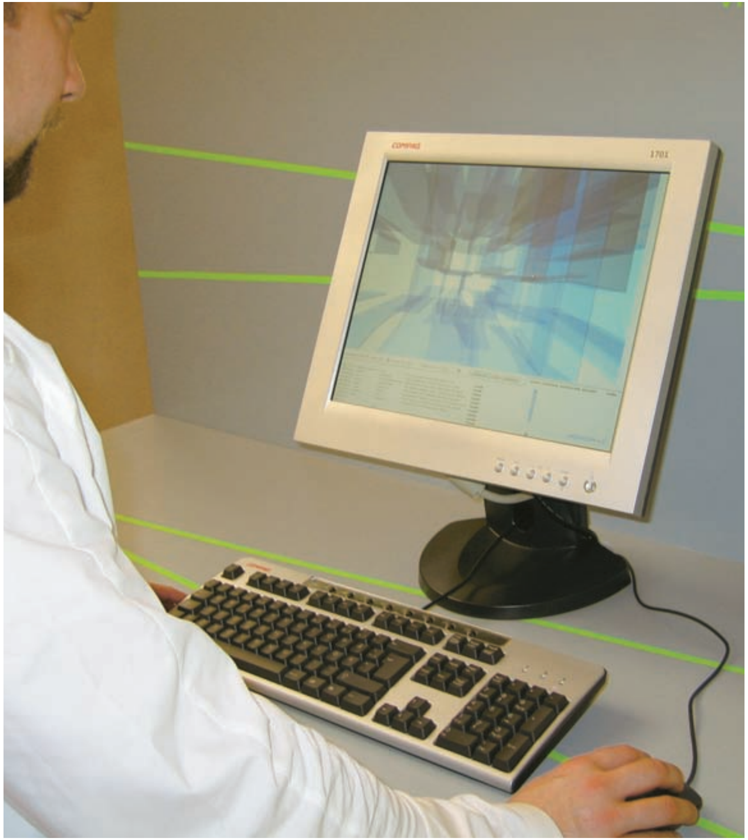
Presentations:
Urbantoys v.1 was presented at the *CRAC* exhibition at Liljevalchs, Stockholm and the *N2art Nordic Netart* on-line exhibition in 2000. *Urbantoys v.2* was first presented at *Reshape!*, organized by IASPIS, at the 50th Venice Biennale in 2003. The project has also been presented at the *Prototypes for Performative Design* seminar (2003), the *onedotzero_stockholm* event at Moderna Museet, Stockholm (2005) and the *AKAD* exhibition at Lunds Konsthall (2006).

Special thanks:
CRAC, IASPIS and AKAD

Urbantoys v.2 design loops:
The *UT1 Urbantoys v.2 System Development* design loop looks at the potential of the Virtools parametric software as a collaborative design environment for the project, which allowed constant testing of the performative aspects of the design system, and made the parametric behavior available to modification from outside parties.

The *UT1 Urbantoys v.2 Performance* design loop presents the way the project has been perceived and explored, in its presentations at different venues. The focus lies on the project´s physical manifestations, the conceptual framework that has supported it, and its dependence on the design system itself.

The concept of the ***design project is further developed in the text book*** ↓ [P.12 | P.44].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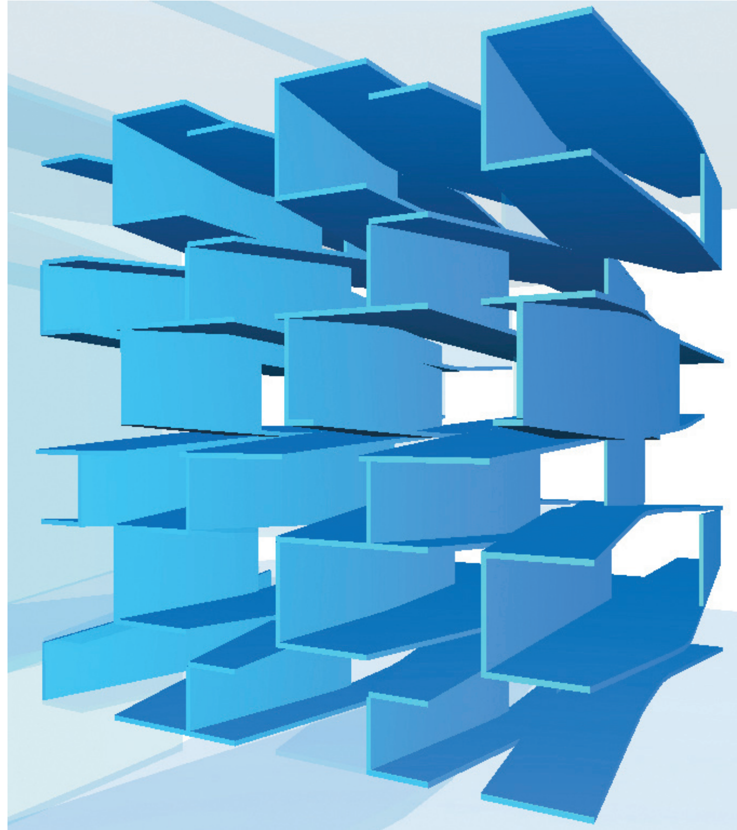
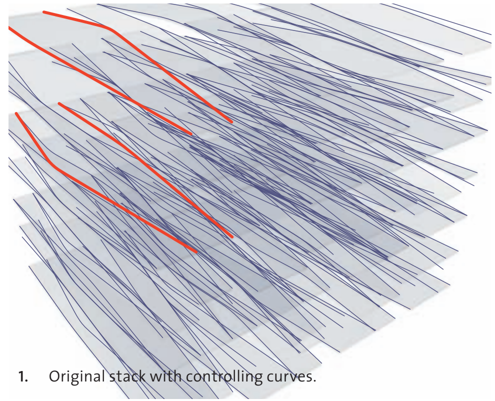


UT1 Urbantoys v.2 System Development

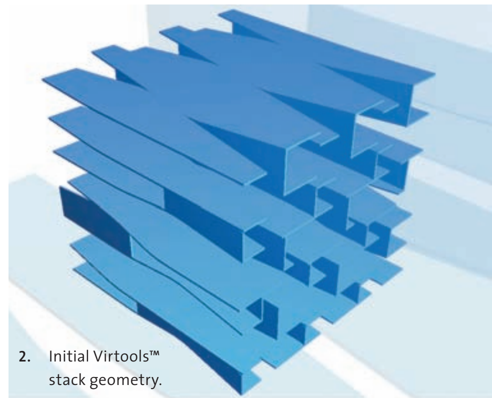
The development of the Urbantoys v.2 project was based on an initial given geometry originating from one single curve, rotated in one of four diagonal positions, in effect creating a profile that is deformed both horizontally and vertically. Each singular object of the geometry is formed by two configurations of that curve, forming a primary system of horizontal, but deformed slabs. These slabs were associated vertically in couples through the introduction of a subsystem of vertical members or partitions, partially enclosing each set. In order to introduce user-controlled modifications of the system, the geometries imported into the Virtools™ game development as neutral slabs (completely flat), in horizontal and vertical configurations for all primary and subsystem objects. These geometries could then be associated through the development of custom scripts, that defined the interface and views, the way all objects could be modified by a user, and how different objects would affect each other during these modifications. The initial neutral state of the stack is transformed at the start-up of the Urbantoys v.2 browser, as all the vertices of each object are moved into positions defined by the

The Virtools™ software was used to establish relationships and behaviors between geometrical objects in the development of the Urbantoys v.2 browser. This is very similar to the parametric development in packages such as GenerativeComponents (GC), but is focused on the creation of responsive environments open to interaction from any party (e.g. games). While GC is integrated into Bentley's Microstation CAD package, and can only operate in that environment, Virtools™ exports independent and stand alone parametric environments. Geometries are not created in Virtools™, but are rather imported as polygon models from any of a number of other packages. Dependencies and behaviors are then added using a graphic scripting interface. Rather than using a timeline principle for handling interaction and transformation, Virtools™ uses a network structure driven by a clock pulse principle, much like a logical circuit with gates, input/output parameters and Boolean operations. The Virtools™ development interface contains a schematic view, in which the relationships between actions and objects can be defined using a list of behavior building blocks. A 3D layout window allows the simulation of the current set-up, including user interaction. The graphic building blocks in the schematic view can be encapsulated into groups, in effect creating new user-defined building blocks that can be repeated in the project or shared between different projects and developers.

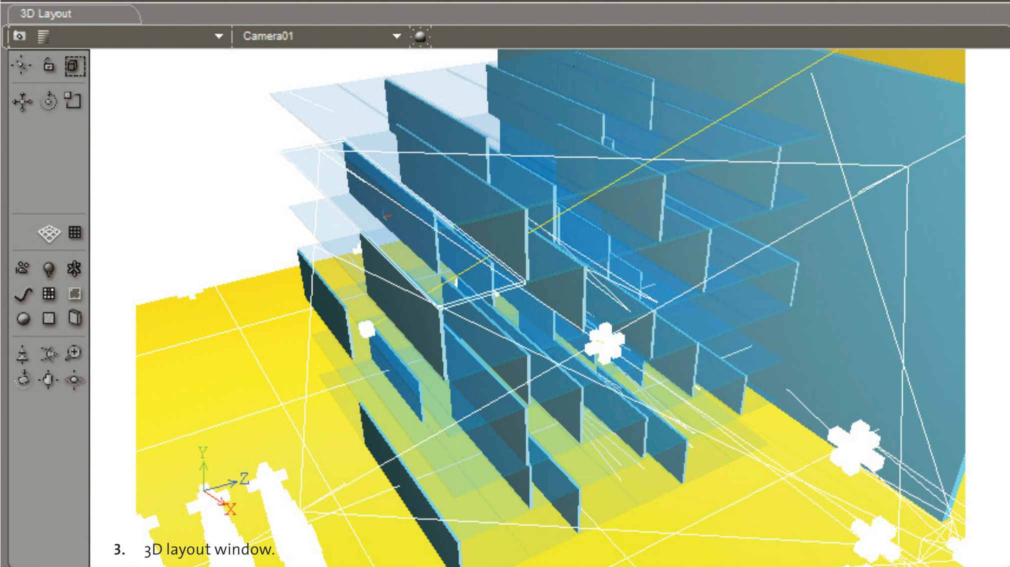
1. Initial stack geometry with the four configurations of curves in red (showing only horizontal primary system objects).
2. Initial stack geometry in Virtools™ (showing horizontal primary system and vertical subsystem objects).
3. 3D layout window showing neutral state of stack.
4. Virtools™ building blocks; the behaviors that can be applied to all geometrical objects, include a wide range of modifications such as interface features, logical calculations or geometrical deformations.
5. Virtools™ schematic view of selected Urbantoys graphic scripts, with the network that directs the clock pulse.



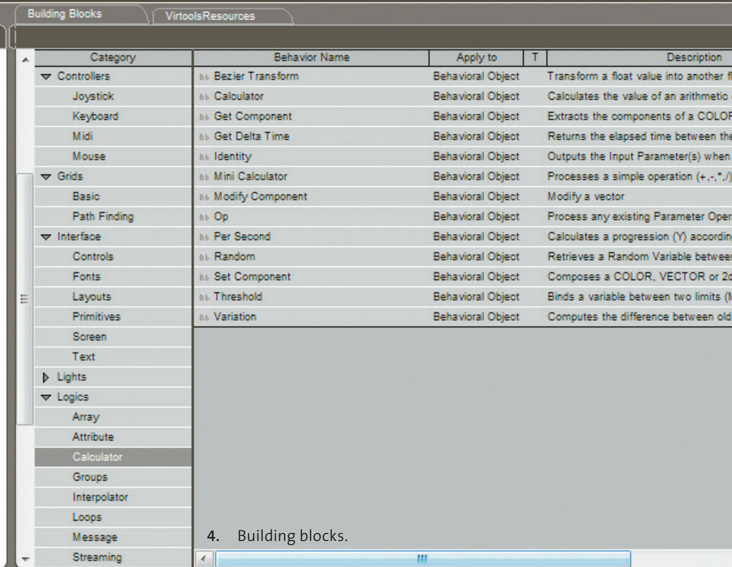
1. Original stack with controlling curves.



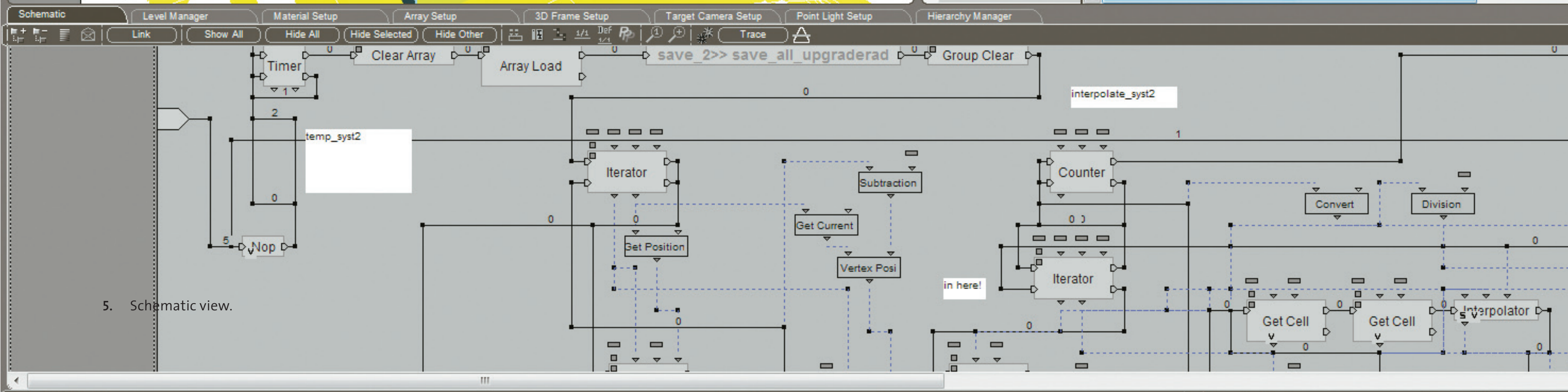
2. Initial Virtools™ stack geometry.



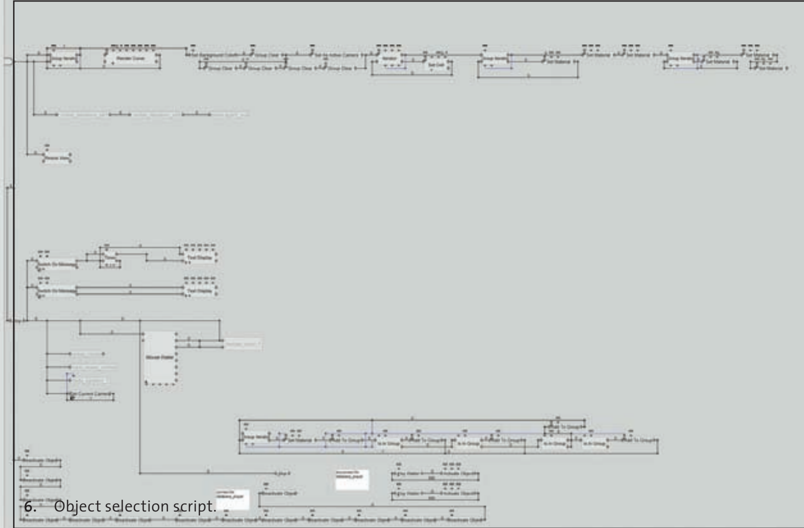
3. 3D layout window.



4. Building blocks.

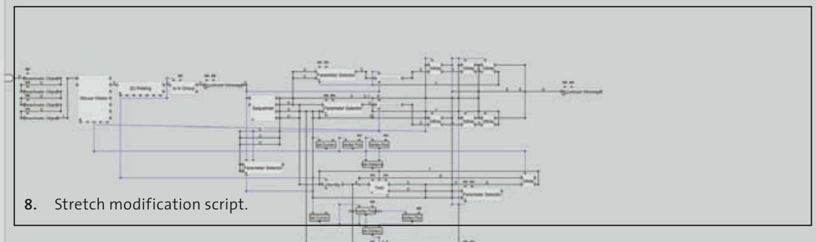


5. Schematic view.

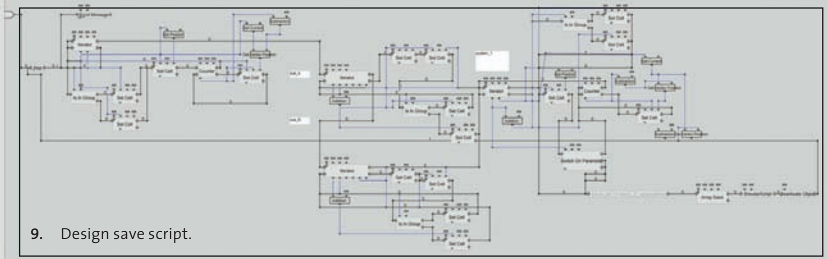


6. Object selection script.

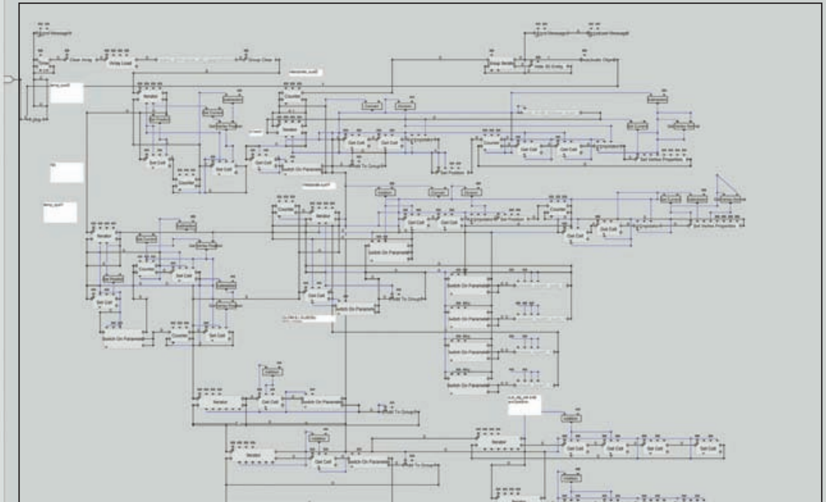
7. Object to curve alignment and transformation script.



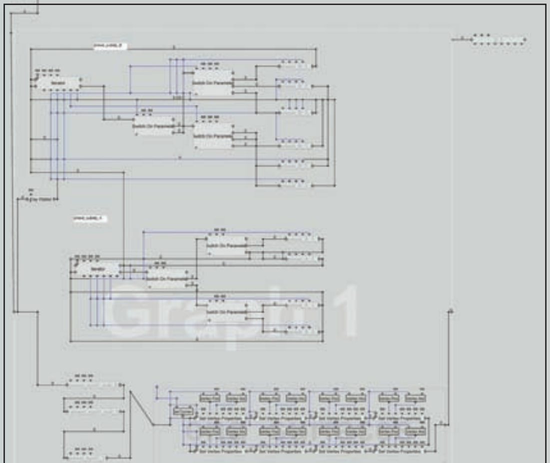
8. Stretch modification script.



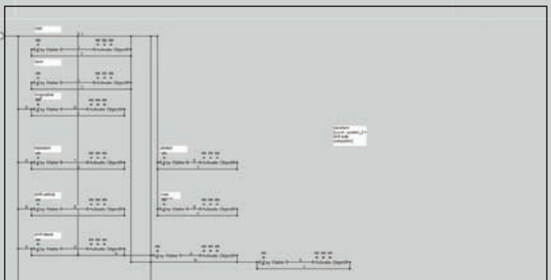
9. Design save script.



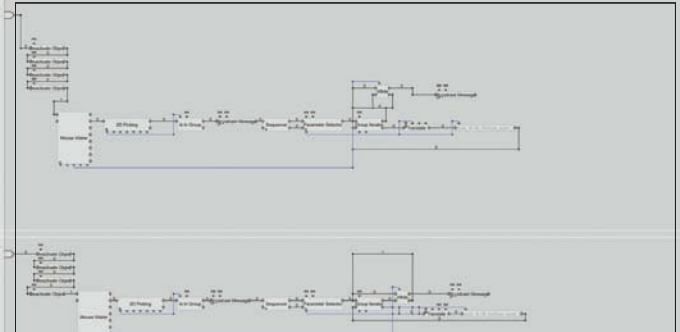
10. Design load script.



11. Subsystem adaptation script.



12. Pre-release modification control scripts.



13. Vertical shift modification scripts.

14. View change scripts.

original curve profile and its rotated configuration. The final modifications open to the interaction of the user of the system were based on the 3-dimensional grid of the initial stack, such that the shift and stretch modifications always follow the extruded form of the primary and subsystem objects (i.e. there is never a stretch or shift that modifies the controlling profile curve of the geometry). Modifications of the profile of each object are treated differently, in the form of a triggered transformation that morphs the profile of the selected object into a new state, based on the change of the controlling curve profile. This allows an iteration between four states following the four rotational states of the controlling curve, while retaining other qualities directed by prior modifications of stretched dimensions or shifted positions. The perceived effect of these modifications was also considered important, and all changes induced by the user would be performed through minute incremental shifts, and the vertices would move from one spatial position (x, y, z) to another through a series of interpolated states, creating the effect of a smooth change of form and location.

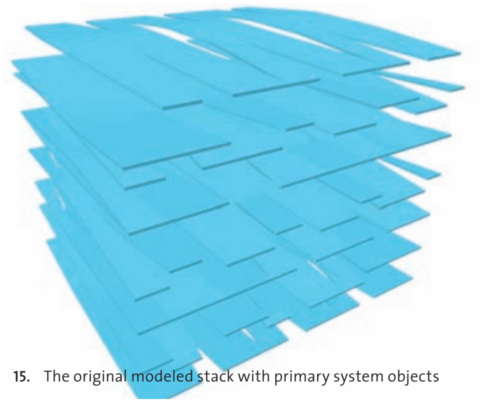
While a user can simply rotate and view the current design by using the mouse in a very simple way, any modification requires a selection of objects of interest. Any number of primary or subsystem objects may be selected, and any modification triggered would affect all of them. This set-up once again required the establishment of a relation between the objects. Primary objects rule over subsystem objects, as parents in each set of two primary and two subsystem objects. A transformation of the curve profile of a primary object also affects its sibling, in the way that all subsystem objects continuously adapt to any change in the primary system. In addition, each subsystem object can be transformed directly in a very limited way; the side or the end of the primary object that it is related to can be mirrored. The save and load features depended on the use of an .asp-database, that communicated with the browser through the use of simple .txt files loaded as arrays or 2d matrices holding the data, including the spatial position of each vertex of all objects in the scene. Again, the reconfiguration of the system into a loaded design is transformed through interpolation, creating the impression that the system morphs into its new state. The user could also input other information to his/her design when saving, which would be stored in the .asp-database associated with the libraries of .txt files.

The performative qualities and effects of the system did not only apply to its geometrical modifications and transformations. The view of the user is affected by the selection of objects, in the sense that the system always directs the view towards the “center of gravity” of the all selected object. The user may rotate the view through simple mouse movements, but the focus remains on the object susceptible to modification. In a way, the experienced user can thereby navigate by selecting objects in the periphery of the screen. There are also two general views available, top and lower level perspective, which can be manually changed by the user. Again, the view shifts smoothly from one to another through custom scripts that interpolate between different cameras in the system. The Virtools™ environment was also used to proto-

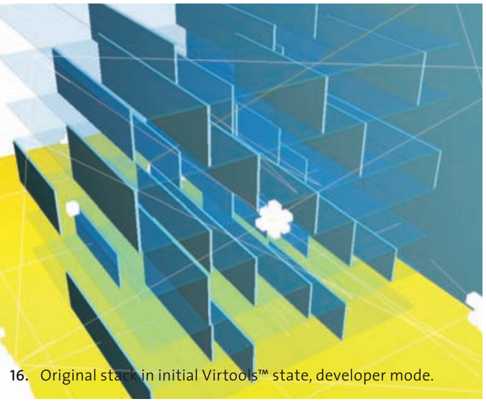
6. The object selection scripts control how the user can select objects for manipulation, highlighting it in solid blue as it is chosen.
7. The object to curve alignment and transformation script modifies the object according to a specific curve profile. The transformation is performed in very small increments, making it appear to smoothly morph from one configuration to another. This script is run on each object when Urbantoys v.2 is initiated, altering the neutral blocks to the specific curvature, but it also operates when the user selects the transform modification.
8. The Stretch modification script allows the user to stretch the primary objects horizontally. The script flips between enlarging and reducing the width of the object between each trigger of the modification.
9. The design save script allows the user to save a design. Virtools™ then reads the spatial coordinates of each polygon

vertex in the model and writes this information into a temporary .txt file. The .asp database then adds information from a form filled out by the user, and re-saves this compilation into another .txt file.

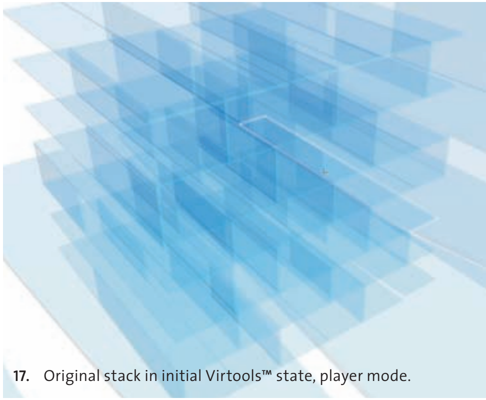
10. The design load script allows the user to select a previous design by name, retrieves the appropriate stored .txt file and modifies the complete model into the saved configuration by moving each vertex to its saved position. This is performed in small increments, thus appearing to smoothly morph from the previous configuration into the stored one.
11. The subsystem adaptation script runs continuously to adopt the subsystem objects to the configuration of their parents. In incremental changes, the subsystem will follow each iteration of the primary system object modification.
12. The pre-release modification control scripts allowed proto-typical tests of the performance prior to the html/asp set-up of the complete browser interface.
13. The vertical shift modification script controls the vertical movement of primary system object when triggered by the user.
14. The view change scripts allow the user to change between a top and lower level perspective view. It operates by smoothly shifting between two preset cameras, both of which continuously adopt their views depending on the selected objects.
15. In the original stack modeled in conventional modeling package, each primary system object was developed by separate profiling curves.
16. When imported into Virtools™, the stack initial form is based on neutral blocks (image shows developer mode of subsystem objects as solid and primary system objects as transparent).
17. When the player is initiated in the Urbantoys v.2 browser (or in simulation in the developer environment), the stack first remains in its untransformed neutral state.
18. The stack immediately transforms to the state defined by the controlling curve profiles.



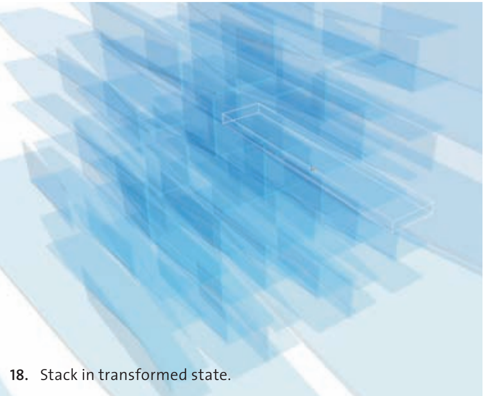
15. The original modeled stack with primary system objects



16. Original stack in initial Virtools™ state, developer mode.



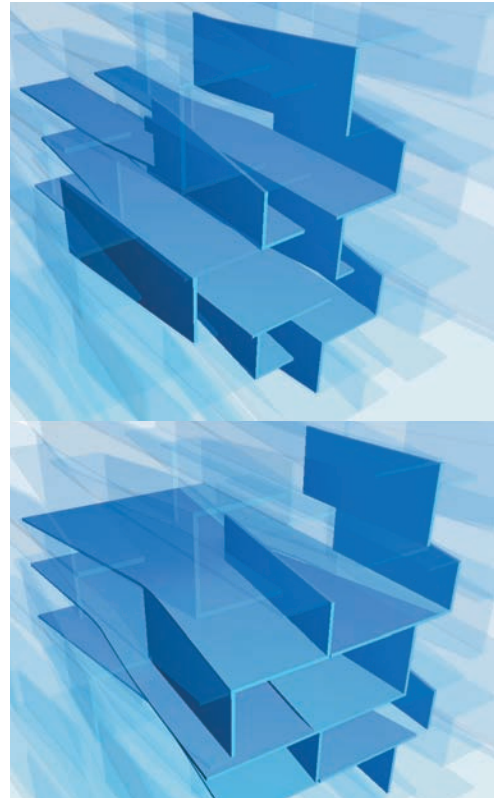
17. Original stack in initial Virtools™ state, player mode.



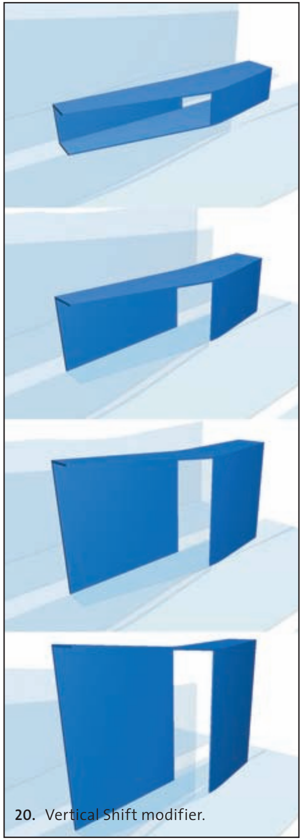
18. Stack in transformed state.

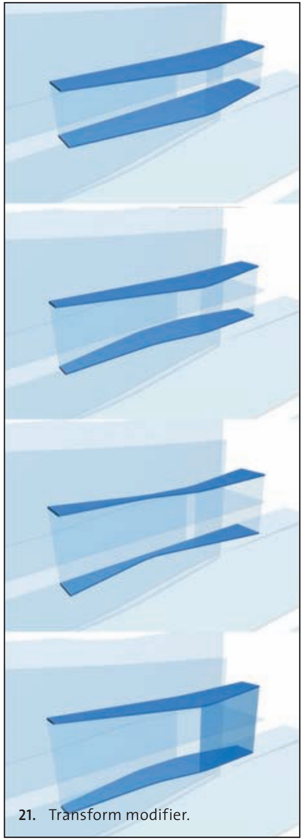
type the type of modifications to be implemented. The possibility of creating complex encapsulated scripts allowed collaborative development of different aspects of the system in parallel, as well as an iterative approach in which the developed system could be tested and re-developed depending on its performance. The different parts of the system could be separated and developed in isolation, with compilation and testing of the complete system at regular intervals, allowing for a commission-based collaboration through which behaviors would be tested by the individual developer, to be contextually evaluated later in comparison with other features in the compiled prototype. The development of the Urbantoys v.2 browser was aimed at performative effect, and how the modifications and transformations would be perceived and experienced by a new or experienced user. In this sense, the task at hand was to develop an intuitive design environment that allowed anyone to interact with the digital design space, while also adding the experiential effect of this environment as a factor for appreciation from the user. The geometrical form and design identity, as given by Servo, is certainly an important part of this, as is the idea of sampling designs submitted by prior users and the potential manufacturing part. A vital aspect which is unique to the development is the experiences of the manipulations, including the way a user navigates the digital design space, as well as the temporal aspect of morphing and the logics of each modification. In a way, the complete development of the system regarded the definitions of a solution space that includes experiential effect and performative qualities not only of the resulting proposals, but of the design space itself.

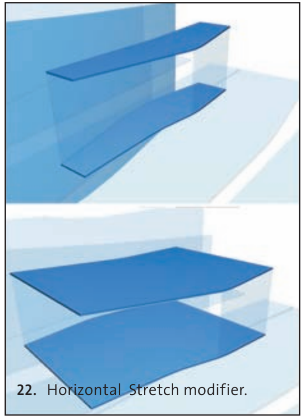
19. The selected primary and subsystem objects susceptible to user modification are indicated as solid, while the currently unaffected parts are transparent.
20. Example of a Vertical Shift modification of one primary system object. Note that the subsystem objects are adapting to the shift of the top primary system object.
21. Example of Transform modifier when applied to two primary system objects, showing the four different configurations made possible by changing the controlling profile curve.
22. Example of Horizontal Stretch modifier when applied to two primary system objects. Note that the subsystem objects are moving to accommodate for the changing dimensions of the primary system objects.
23. Example of subsystem object Transform modifier, which mirrors the configuration of the affected objects, while maintaining the adaptation to the primary system objects..
24. Example of Vertical Shift modification of two grouped primary system objects, which in effect moves the complete set (primary and subsystem objects) as one unit.
25. Example of Longitudinal Shift modification of two grouped primary system objects, which in effect moves the complete set (primary and subsystem objects) as one unit.

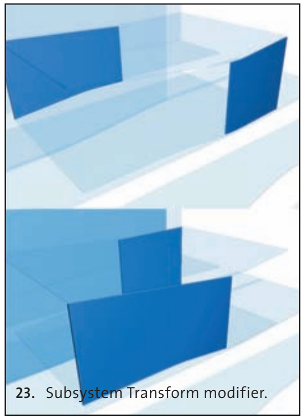


19. Selected objects as solid objects.

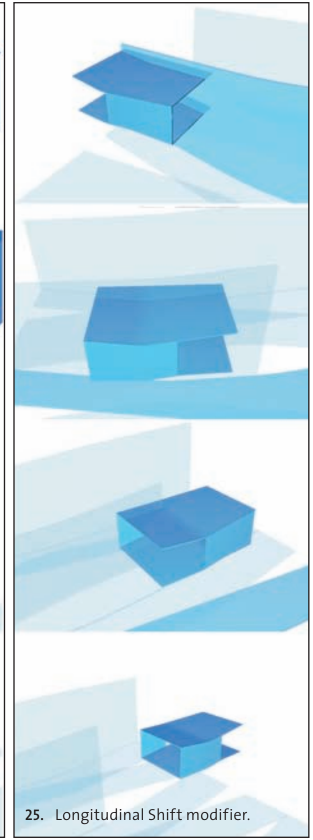

20. Vertical Shift modifier.


21. Transform modifier.


22. Horizontal Stretch modifier.


23. Subsystem Transform modifier.


24. Vertical Shift modifier, 2 objects.

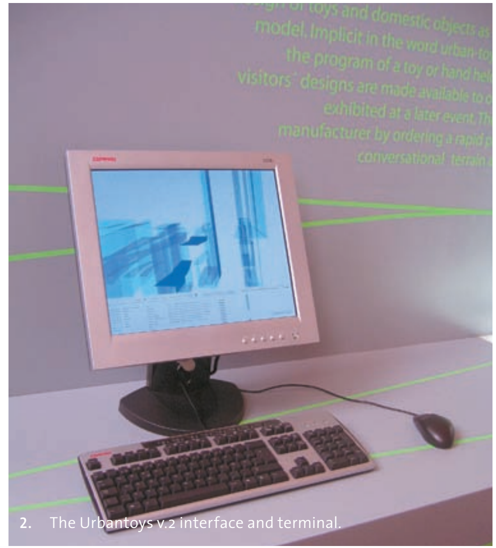

25. Longitudinal Shift modifier.

UT2 Urbantoys v.2 Performance

The Urbantoys projects perform in parallel on a conceptual/speculative level, and on an instrumental operational level. The interactive design system at the core of the project is supported by the conceptual framework that provides a contextual speculation of a fully functional project, in which the collaboratively designed proposals can actually be fabricated and delivered through a network based on existing technologies. The Urbantoys v.2 interface was not only designed in game development software, it also has connotations to games in other ways. There is an underlying order of interaction, based on the defined modifications, that supplies rules that are quite simple to understand, but may produce results that are rather unpredictable, in spite of the fact that the controlling curve profile is ever present. The ***performance and effects*** ↓ [P.16 | P.26 | P.40 | P.44]. of the modifications and transformations induced by the user are also designed to be suggestive and articulate dynamic and temporal aspects of the system. This is provided both for legibility (to understand what kind of transformation is underway) and as a vital part of the atmospheric effect of the system (it behaves in a certain way, rather than being manipulated into a preferred configuration). In many ways, it based on a system of transitions, rather than on an additive or subtractive model. Many of the user-triggered manipulations are not readily controlled, in particular in regards to the transformations of the primary system objects, and the way that subsystem objects adapt to them. In this sense, the system acquires identity, and behaves in a very particular

1. As a part of the second installment of the Urbantoys v.1 project for the N2art on-line exhibition, a conceptual diagram was developed featuring the important notions of design activity, a catalogue for sampling, information on potential manufacturers, and an outline of how a physical instantiation may be delivered. This version was meant to be explored on-line at any physical location, which required an informative digital context surrounding the actual browser.
2. The Urbantoys v.2 project performs only locally, and is set up as a workstation, which can be supported by additional information and props, here at the Reshape! sideshow at the Venice Biennale 2003.
   Image 3 – 8 shows a sequence of user interactions.
9. The additional material provided with the Urbantoys v.2 project when installed included pre-designed proposals, with additional short information. The aim of this material, presented as laminated cards, was to suggest user interaction and the cataloguing of additional information, including the author's personal view of the submitted design. This material was in fact developed during prototyping in the system development.

1. The Urbantoys v.1 conceptual diagram.



2. The Urbantoys v.2 interface and terminal.

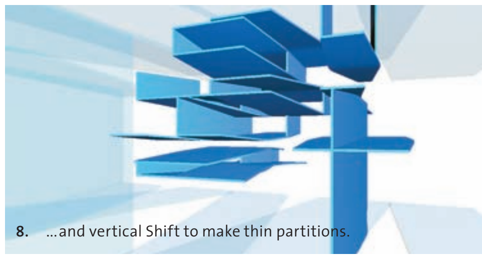
3. User interaction, selection of objects...

4. ...and rotation for a better view.

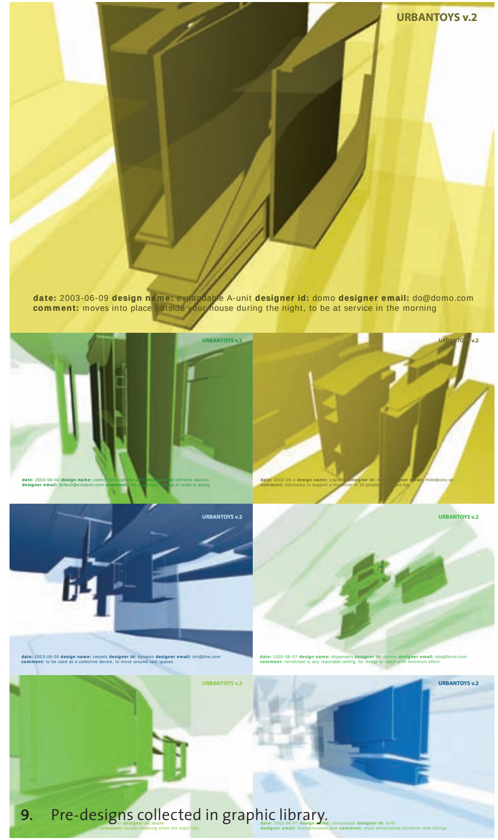
5. Applying horizontal...

6. ...as well as vertical Stretch modification...

7. Using vertical Shift to make sets thinner horizontally...



8. ...and vertical Shift to make thin partitions.



9. Pre-designs collected in graphic library.

way. The Urbantoys v.1 project was implemented primarily as a physical installation with a local workstation, and later as an on-line design environment accessible directly through the internet. The Urbantoys v.2 project was developed only as a local workstation, with a supporting physical installation that provides legibility and context for the project. Its various instances have utilized different means to provide the atmosphere needed for both immersion in the experiential design environment, and an understanding of the speculative supportive network. In particular, all instances of the projects feature a workplace. In the original *Reshape!* exhibition, this was designed in the form of a freestanding composite workbench/workstation/information board, around which visitors could not only use the design browser, but also handle example models and review prints of previous designs. At Lunds Konsthall, the project was immersed in the presentation of the Krets overall activities, and becomes an operational example of the design and production technologies discussed in the general research, or a game that alludes to a younger generation. At the *onedotzero-stockholm* installation, it acted as a pastime activity between the screenings of progressive moving images in the nearby auditorium, providing a relief from other, more intense, media experiences.

10. Urbantoys v.1 was first installed as a physical installation as a part of the *crac* exhibition at Liljevalchs Konsthall in 2000. The provided space was turned into a lounge-like area with sideboards, a separate workstation for visitor interaction and lounge chairs with a view of a projection of the design interface.

11. At the *onedotzero-stockholm* festival at Moderna Museet in 2005, Urbantoys v.2 was set up outside the main auditorium, as a pastime event between movie screenings.

12. The onedotzero-stockholm installation featured information integrated into the table itself, to allow the user to quickly understand the concepts explored when interacting. A backlit keyboard provided light for design submittal and retrieval in the semi-light conditions.

13. The *AKAD* exhibition at Lunds Konsthall in 2006 provided a full presentation of the work of Krets, including several design projects, as well as documentation of workshops and seminar. The exhibition was based around a long wall-mounted table, with two workstations featuring the Krets website as well as the Urbantoys v.2 browser.

14. The workspace at Lunds Konsthall provided a working place inside the exhibition, in which visitors could spend time exploring the browser.

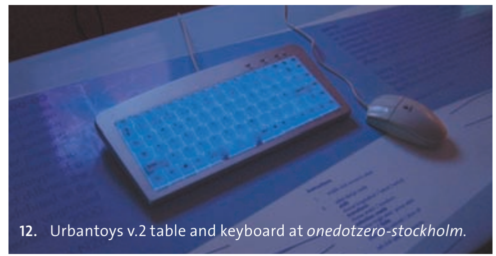
15. For the *Reshape!* exhibition in 2003, the project depended on a larger physical structure to give it a supporting structure in the gymnasium space used for this Venice Biennale sideshow. The installation featured an integrated stand-up workplace for the browser workstation, a light table for physical models and pre-design laminated cards, and a large display providing additional information for the user.

16. The *Reshape*! exhibition installation allowed several people to interact with other parts of the project other than the browser.

17. The *Reshape!* exhibition also featured physical models produced using a 3D printer, operating as props that support the conceptual framework of the project.

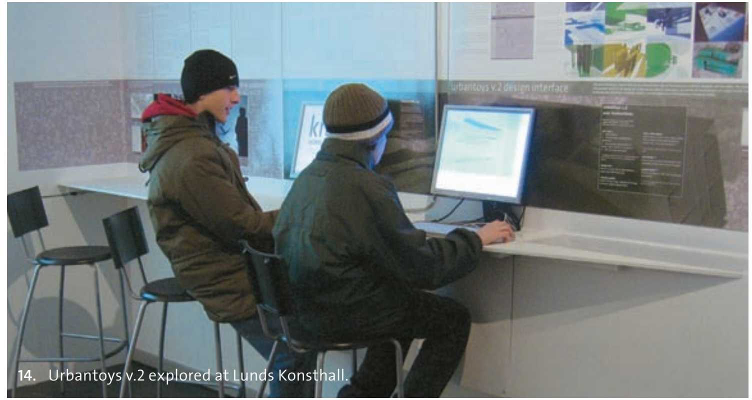
10. The Urbantoys v.1 environment at the *crac* exhibition.

11. The Urbantoys v.2 explored at *onedotzero-sthlm*.



12. Urbantoys v.2 table and keyboard at *onedotzero-stockholm*.

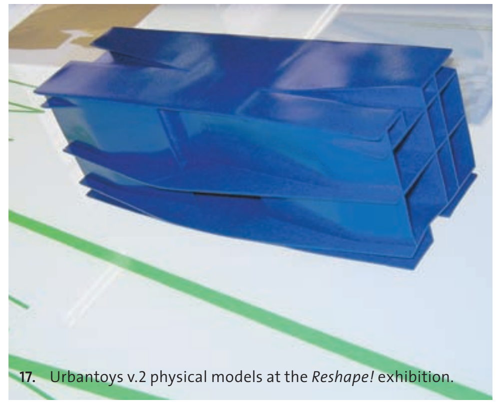
13. Urbantoys v.2 installed at Lunds Konsthall.



14. Urbantoys v.2 explored at Lunds Konsthall.

15. Urbantoys v.2 installed at the *Reshape!* exhibition.

16. Urbantoys v.2 explored at the *Reshape!* exhibition.



17. Urbantoys v.2 physical models at the *Reshape!* exhibition.

Teaching Design Studios

The contexts for the student projects presented in these design loops include the Informed Modularity and Architecture InFormation design studios (4th year, KTH School of Architecture, 2006–2008). Both studios have re-considered the history of systems and components in post– war 20th century architecture. They have also re-examined the implications of a componental approach in contemporary architectural design practice, including the modularization of skill and expertise, industrial production and construction systems.

The students worked in teams with intense introductions to ***new parametric design*** ↓ [P.16] software as a foundation, and continuous discussion around developed digital design systems as mode of operation.

The specific student projects have been selected because of they are clearly presenting the issues addressed in these design loops. While they also all encompass other qualities as well, they are not necessarily representative of the studio as a whole. All projects were partly based on parametric systems developed in GenerativeComponents (GC), but also included a number of other techniques and concepts, not covered extensively here.

Teaching Design Loops:
The *TDS1 Parametric Material Fabrication* design loop presents work that links parametric design systems with the material constrains of physical prototyping, operating in an interior scale.

Project 1 and 2 were developed in the first semester of Architecture Information in the fall of 2006, with tutors Jonas Runberger and Thomas Wingate. Project 1 student team: Petter Forsberg, Magnus Hofverberg and Tove Leander. AIF studio fall 2006. Project 2 student team: Paul Goodall, Raimo Joss and Alexander Trimboli. AIF studio fall 2006.

The *TDS2 Parametric Massing* design loop explores conceptual spatial relational modules and massing concepts, in the development of architectural organization strategies.

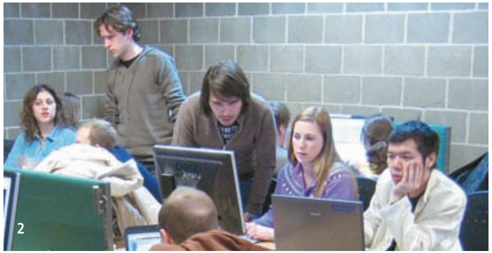
Project 3 was developed in the Informed Modularity course in the spring of 2006, with tutors Jonas Runberger and Pablo Miranda. Project 3 student team: Andrew Martin, Alessandra Pantuso and Sanna Söderhäll. Project 4 was developed in the 1st semester of the Architecture InFormation studio in the fall of 2007, with tutors Ulrika Karlsson and Jonas Runberger. Project 4 student team: Petra Lindfors, Robert Volz and Henric Wernefeldt.

Credits and Teaching team IM + AIF:
The Informed Modularity design studio (IM) was conducted at the KTH School of Architecture during the academic year 2005-2006. The Architecture InFormation design studio (AIF) was conducted at the KTH School of Architecture during the academic year 2006–2008. Ulrika Karlsson (studio responsible IM and AIF), Jonas Runberger (coordinator IM and AIF fall 2006, tutor AIF fall 2007), Pablo Miranda (tutor IM), Thomas Wingate (tutor AIF fall 2006), Erik Hökby (tutor AIF spring 2007), Petter Forsberg and Alexander Trimboli (teaching assistants AIF fall 2007). **www.arch.kth.se/aif**

Special thanks to:
Volvo Car Corporation, Solidmakarna, Skanska, Scheiwiller Svensson Arkitektkontor, Tyrens, BSK Arkitekter, FFNS, Equator, CAD&OFFICE.

1. Final review with invited critic Torsten Livion, and tutors Ulrika Karlsson, Pablo Miranda and Jonas Runberger, IM fall 2005.
2. Fabricate/Device workshop, a collaboration with the Diploma 16 unit of the Architectural Association, IM fall 2005.
3. Students in the Info_liations / Ex_foliations, a workshop at SIAL, RMIT in Melbourne, conducted by Marcelyn Gow, Daniel Norell and Jonas Runberger, 2003.
4. Student project by Petter Forsberg, Magnus Hofverberg and Tove Leander, AIF fall 2006.
5. Student project by Mania Aghaie and Margit Weiss, AIF fall 2006.
6. Student project by Andrew Martin, Alessandra Pantuso and Sanna Söderhäll, IM fall 2005.
7. Student project by Paul Goodall and Alexander Trimboli, AIF spring 2007.

1

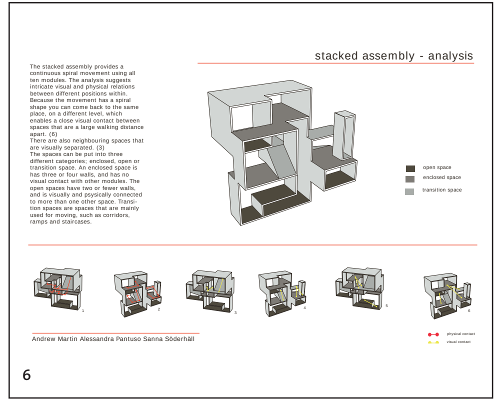


2

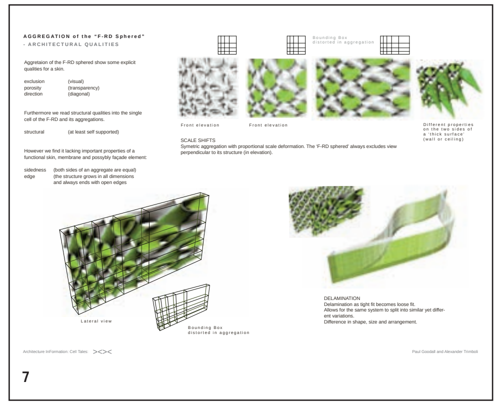
3

4

5


stacked assembly - analysis
The stacked assembly provides a continuous spiral movement using all ten modules. The analysis suggests intricate visual and physical relations between different positions within. Because the movement has a spiral shape you can come back to the same place, on a different level, which enables a close visual contact between spaces that are a large walking distance apart. (6)
There are also neighbouring spaces that are visually separated. (3)
The spaces can be put into three different categories; enclosed, open or transition space. An enclosed space is has three or four walls, and has no visual contact with other modules. The open spaces have two or fewer walls, and is visually and psysically connected to more than one other space. Transition spaces are spaces that are mainly used for moving, such as corridors, ramps and staircases.
open space
enclosed space
transition space
1
2
3
4
5
6
physical contact
visual contact
Andrew Martin Alessandra Pantuso Sanna Söderhäll

6


AGGREGATION of the "F-RD Sphered"
- ARCHITECTURAL QUALITIES
Aggretaion of the F-RD sphered show some explicit qualities for a skin.
exclusion (visual)
porosity (transparency)
direction (diagonal)
Furthermore we read structural qualities into the single cell of the F-RD and its aggregations.
structural (at least self supported)
However we find it lacking important properties of a functional skin, membrane and possybly façade element:
sidedness (both sides of an aggregate are equal)
edge (the structure grows in all dimensions and always ends with open edges
Bounding Box distorted in aggregation
Front elevation
Front elevation
Different properties on the two sides of a 'thick surface' (wall or ceiling)
SCALE SHIFTS
Symetric aggregation with proportional scale deformation. The 'F-RD sphered' always excludes view perpendicular to its structure (in elevation).
Lateral view
Bounding Box distorted in aggregation
DELAMINATION
Delamination as tight fit becomes loose fit.
Allows for the same system to split into similar yet different variations.
Difference in shape, size and arrangement.
Architecture InFormation: Cell Tales:
Paul Goodall and Alexander Trimboli

7

TDS1 Parametric Material Fabrication

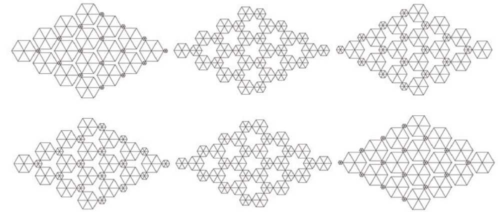
Project 1: Petter Forsberg, Magnus Hofverberg and Tove Leander. AIF studio fall 2006.

Project 1 is based on a repetitive system, designed as a double layer of hexagonal cones, aggregated with a small distance between each unit. The system is then treated as a perforated solid, and variation is created by cutting this solid at an angle, or by an undulating surface. In the first version of the project, the cone assembly remained static once the specific form of the repeated cone was defined. The parametric systems instead dealt with the control of the cutting surfaces for differentiation.

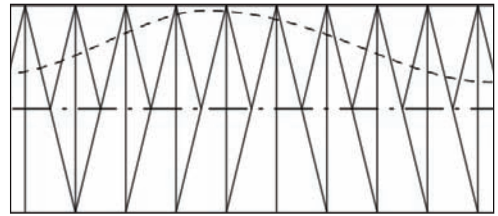
The ***physical fabrication*** ↓ [P.28] part of the project uses the cut digital geometry, and unfolds each cone to find the specific outline generated through the cut operations. The patterns were then used to cut PVC plastic. The repeated form of the original cone allowed the shaping of each individual unit on a single wooden jig by heating the particular areas for the fold lines. The units were painted on the outside of each cone, and all parts were assembled with glue into a self supported but highly perforated honeycomb-like panel. In the final installation, the inside and the outside of each cone take on different color and expression, due to material properties, the paint coat, the angle of each surface as well as shading form neighboring units. The differentiation is very present in the expression of the panel, even though the basic unit is the same. The transparency shifts across the panel, and depending on light and view angle, the assembly appears deep and material (**image 8**) or as a thin silhouette (**image 9**).

In a second version a fully parametric system was developed, in which the angles and depth of the cones were controlled individually through global control surfaces. This enabled a planar cutting surface, achieving a similar effect of differentiated perforation in a straight wall partition.

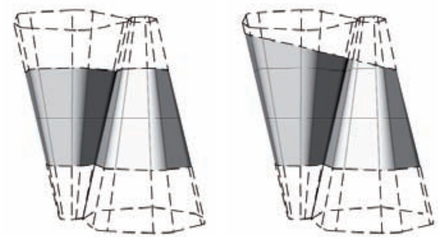
The vertical cross-sections in **image 1** show the relation of the two layers of cones. The **image 2** horizontal cross-section shows the repetitive cones and the undulating cutting surface of version 1. **Image 3** shows cuts as applied to cones of both layers. **Image 4** shows unfolded version 1 cones for fabrication. The rendering in **image 5** shows the contrast between inner and outer cone surface. **Image 6** shows the differentiated cone assemblies and planar cuts of version 2. The wooden jig in **image 7** was used to shape the physical PVC components of version 1. Depending on light conditions, the panel may achieve the deep and material effects of **image 8** or the thin silhouette quality of **image 9**.



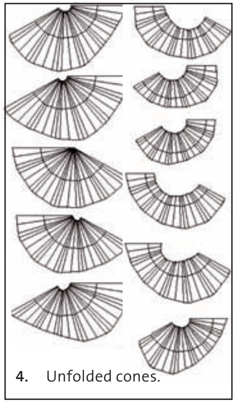
1. Vertical cross-sections of version 1 component assembly.



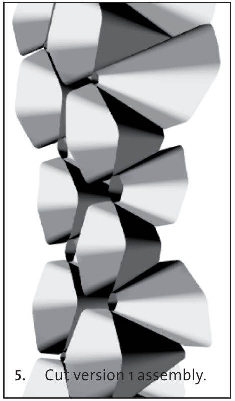
2. Horizontal cross-section of version 1 component assembly.



3. Controlling cut surfaces of version 1.



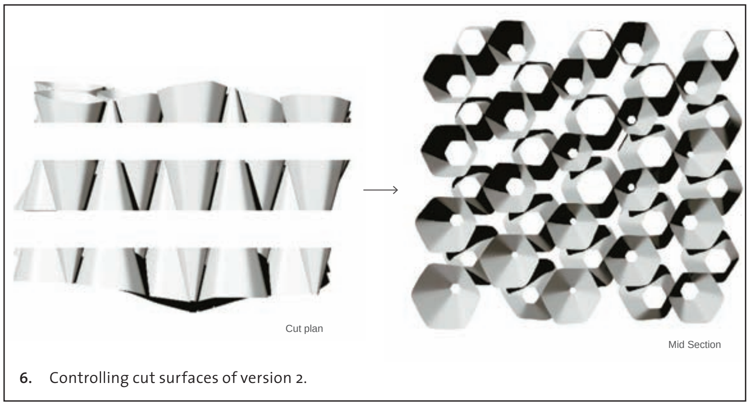
4. Unfolded cones.



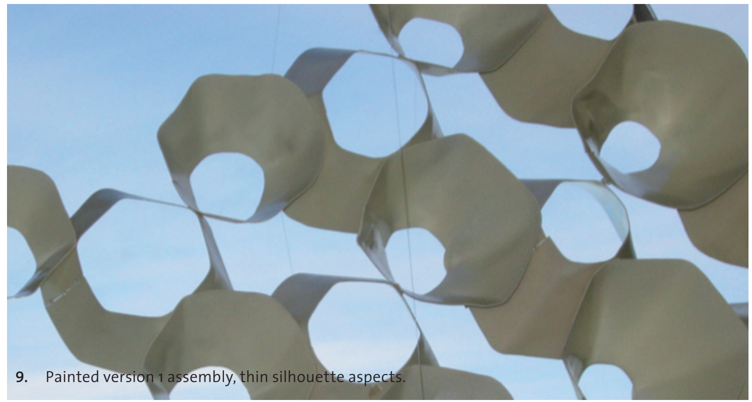
5. Cut version 1 assembly.

7. Wooden jig.

8. Painted version 1 assembly, showing deep aspects.



6. Controlling cut surfaces of version 2.

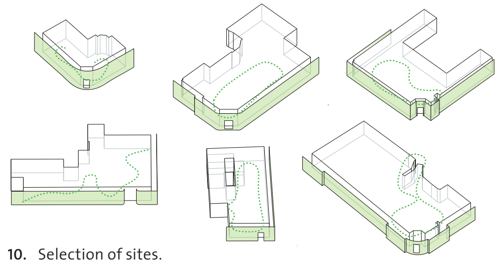


9. Painted version 1 assembly, thin silhouette aspects.

Project 2: Paul Goodall, Raimo Joss and Alexander Trimboli. AIF studio fall 2006.

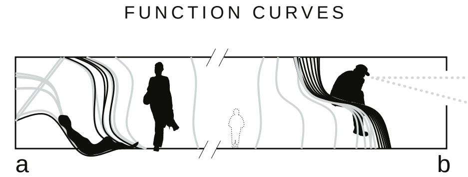
Project 2 takes a starting point in the 10 sites given in the AIF course brief, all interior spaces at street level. The site specific parameters that would inform the ***parametric system*** ↓ [P.16]developed in GC included general spatial data such as floor to ceiling distance and room dimensions, but also projective data such as proposed circulation and programmatic functions based on seating curves. A thick but very transparent partition system was constructed through the layering of thin but stiff sheets, assembled into a truss-like configuration by forming every second layer into a sine wave shape, linked by the horizontally orientated (but also deformed) sheets that take up the tension of the structure. The panel is formed globally by a generated surface based on a manually defined B-Spline curve as well as local parameters. The wave forms sheets gets local specificity by perpendicular alignment to the controlling surface normal in each specific location, with a horizontal as well as vertical effect. The wall system is self supported, reaching the floor at specific points that carry the remaining panel.

Cutting patterns were extracted from the parametric models, and scale models were fabricated with paper simulating the final sheet plastic or composite fabric material. While component set up in the GC model was modularized as one wave length with accompanying horizontal parts above and below, the material logic is based on the continuity of the folded sheets, and a fill scale panel system would benefit from joints differentiated between each level and distributed at irregular intervals.

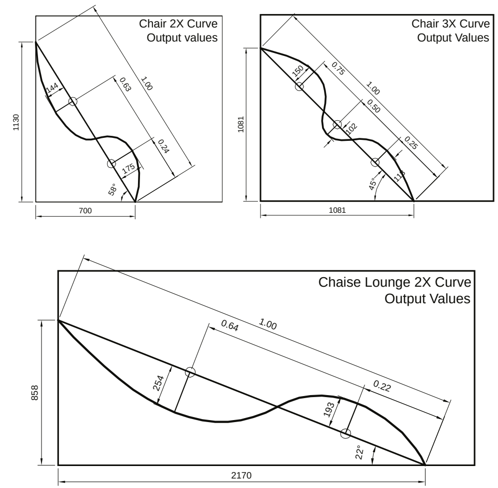


10. Selection of sites.

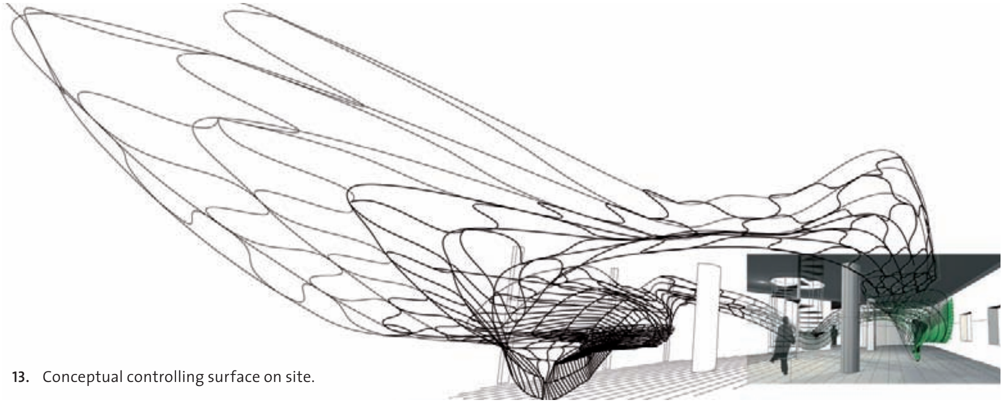
Image 10 shows a selection of the 10 given sites, with B-Spline control curves. The conceptual function curves in **image 11** were set to follow the B-Spline control curves, and were further defined in sets of the parametrically controlled seating curves shown in **image 12**. **Image 13** shows a deployment in an 11th site, the entrance to the KTH School of Architecture. Principles for creating a system of un-foldable surfaces were using two hyperbolic paraboloid surfaces as shown in **image 14**. Each joint between the different surfaces would be locally controlled by curves perpendicular to the control surface shown in red in **image 15**. **Image 16** shows the paper scale model based on the unfolded patterns in **image 17**.



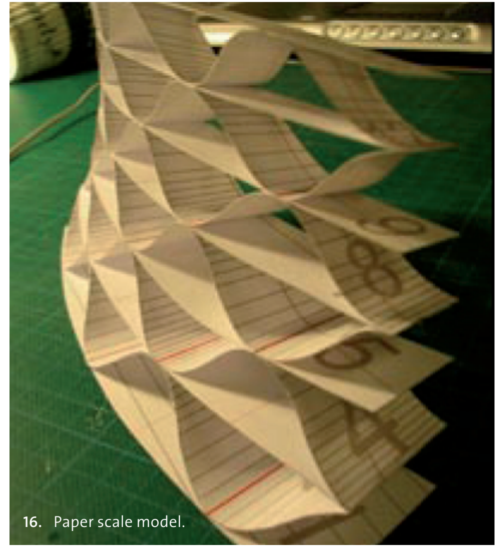
11. Conceptual function curves.



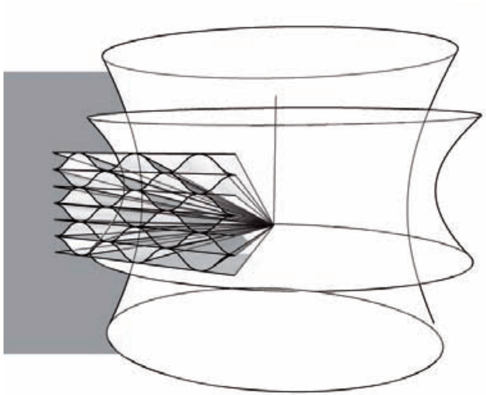
12. Parametric variation of seating curves.



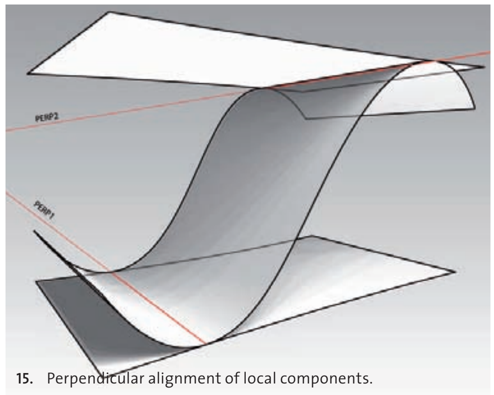
13. Conceptual controlling surface on site.



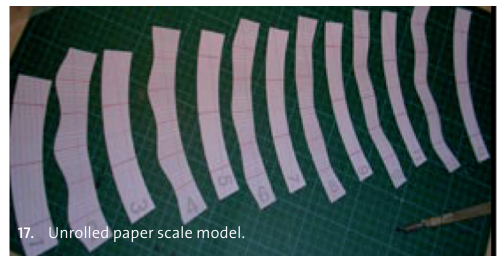
16. Paper scale model.



14. Controlling Hyperbolic paraboloid surfaces.



15. Perpendicular alignment of local components.



17. Unrolled paper scale model.

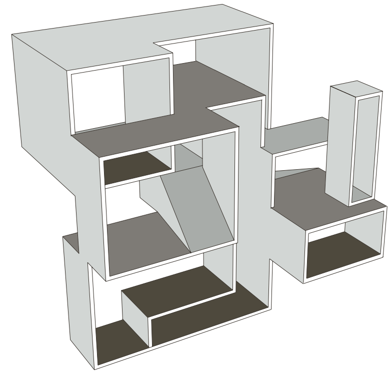
TDS2 Parametric Massing

Project 3: Sanna Söderhäll, Andrew Martin and Alessandra Pantuso. IM studio spring 2006.

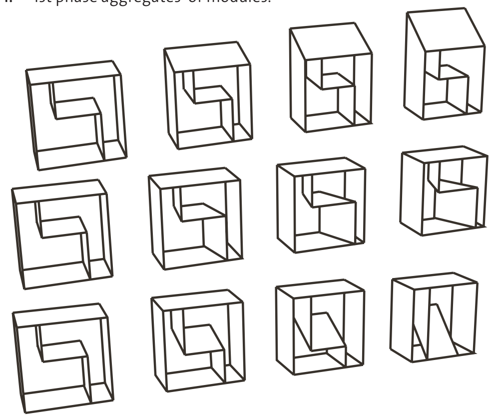
Project 3 started in the definition of a base module operating as an organizational and semi-structural device. Its potential deformation defines the boundaries, formation and division of a spatial unit, both horizontally and vertically. In the first phase of the project, this module was explored in GC through adding one unit to another, step by step into a tree-like structure of dependencies between the modules. The parameters of each module could depend on its neighbors, but could also be controlled individually (with an effect on its children in the chain of dependencies). In the first phase the aggregates of modules followed an ad hoc principle, but still allowed the ***exploration*** ↓ [P.16] of an emerging spatial network, in particular in regards to accessibility of space (some partitions could become vertical communication), visual links and the spatial qualities of irregular shaped rooms. The second phase of development used a scenario of horizontally extended and intertwined row houses, through which the effects of deformation of topologically similar aggregates of modules could be identified and understood. Visual links and spatial qualities would suggest functions of spaces and divisions between different apartments. Iterations of model manipulation and evaluation according to these principles ended in an abstract proposal for 12 housing units intertwined but private from each other, with appended open air gardens.

While the project operates on a very complex level on a spatial and organizational plane, the proposal shows very simple and conventional building components on a structural and ***production*** ↓ [P.30] level. The actual dimensions of the slabs suggested vary a lot, but the joints and interfaces between them may be repeated.

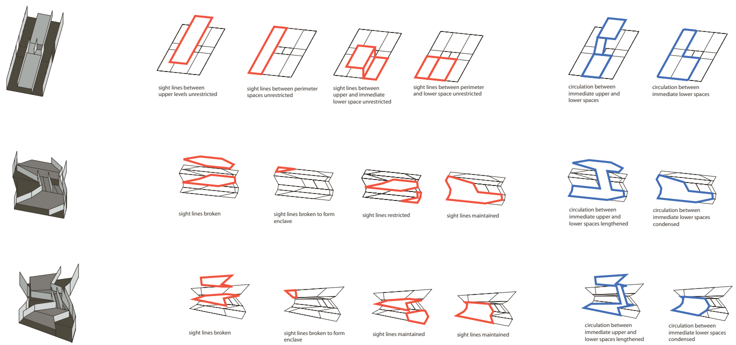
Image 1 shows the first aggregates of the module, using the parametric variations according to **image 2**. Series of studies explored the visual and spatial qualities emerging in deformation variations of a topologically identical structure, in which the links between the modules remained the same, as presented in **image 3**.
Image 4 shows the different housing units color coded, with open gardens in green. Programmatic studies of the resulting spaces in order to find their domestic qualities, as indicated in **image 5**. The rational building production with prefabricated concrete slabs for the external elements of each module is shown in **image 6**, with the small blocks indicating interface links between each prefabricated element.



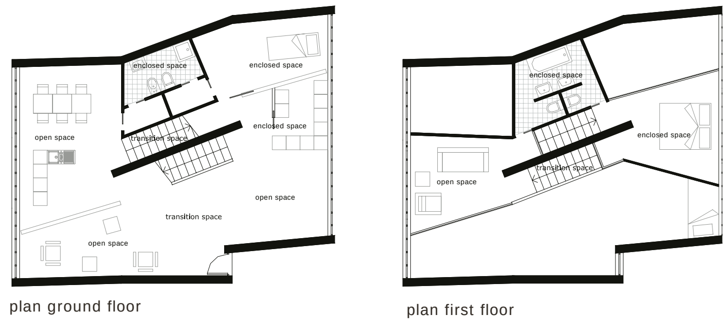
1. 1st phase aggregates of modules.



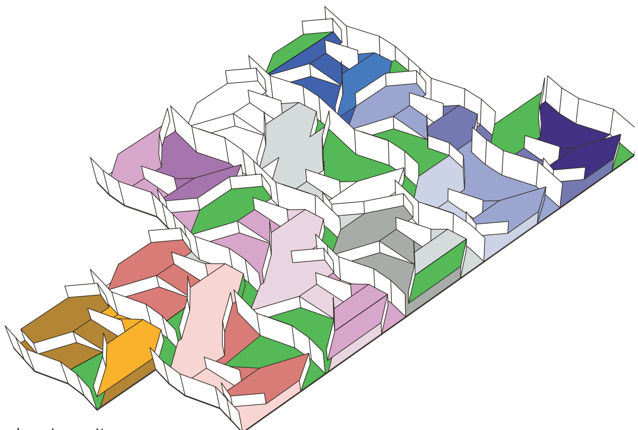
2. Parametric variations of base module.



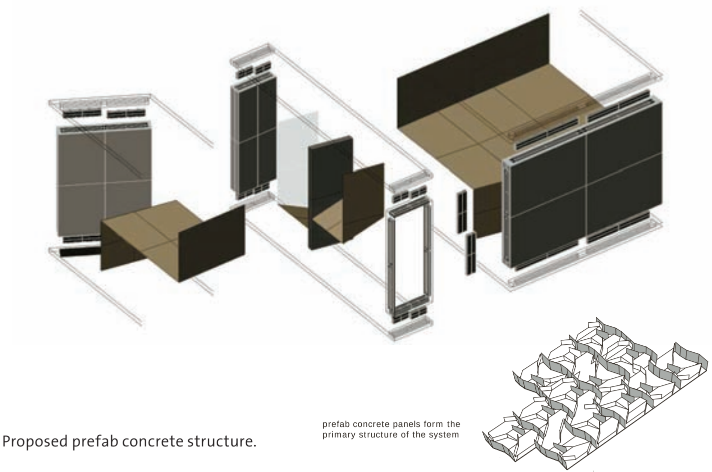
3. Studies of deformations of topologically identical aggregates.



5. Programmatic adaptation of generated aggregate.



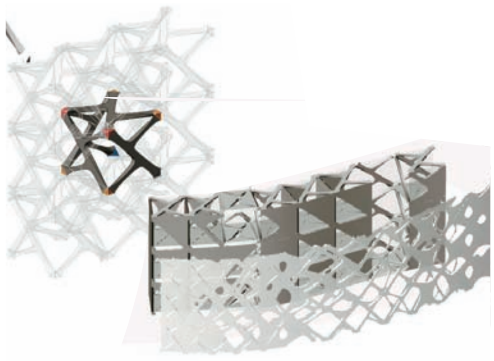
4. Proposal of 12 housing units.



6. Proposed prefab concrete structure.

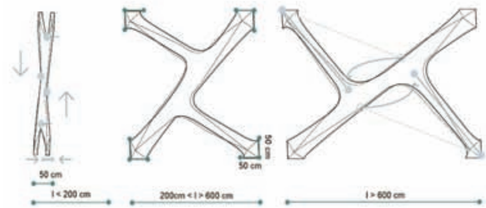
Project 4: Petra Lindfors, Robert Volz and Henric Wernefeldt. AIF studio fall 2007.

Project 4 functions parametrically on two levels. The organizational scheme also defines the massing and consists of a number of layered, overlapped and deformed loops. Boolean-like operations define a number of interstitial zones, and the massing derived is dealing with external massing and overall form, as well as internal mass (enclosures), and void (open space such as atriums or courtyards). In response to the continuous variation of the façade, interior space and horizontal structure in plan, a composite structural component enclosing space was defined. Its dislocated crossbar form made it less legible as an entity in the façade, where aggregates made the borders of the component blurred. In the parametric GC model, the composite component would adapt locally to any global changes of massing. It could also be locally changed in order to alter the ***transparency of the partitions*** ↓ [P.33], which in the façade shifts from a very perforated situation, where the structure is completely visible, through a seamless blurring to a complete solid wall. The proposal suggests a concrete component, which would require unique casts for each part, unless a rationalization process limiting the variation of the components would be conducted.

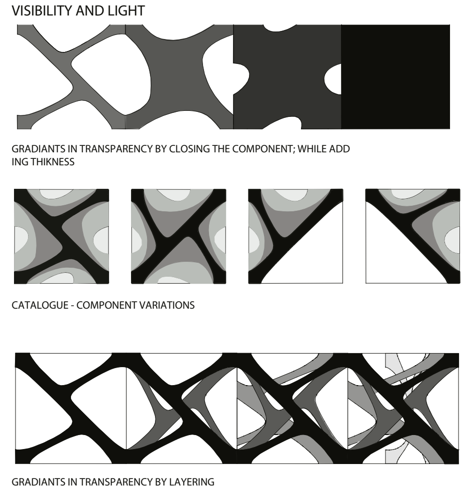


7. Aggregates of the composite component.

Image 7 shows the composite structural component as aggregated into the larger system of deep façade which incorporates programmed space. The component would be deformed locally in response to global changes of the massing models during the design phase, according to the principles in **image 8**. Each space was also gives a definition of privacy through a value of 1–4, which would add local variation of transparency to each component, as shown in **image 9**. Gradients could also be produced through the layering of components. In **image 10** the laser cut models based on the massing models show the layering principle producing variations of mass and void. Further model studies explored the effects of transparency in layered components, as well the spatial interior effects. Laser cut models allowed the exploration of the light properties of the system, as well as the possibility to use a cast concrete component as presented in **image 11**. Digital studies explored the variations of transparency in exterior and interior renderings as shown in **image 12** and **13**.

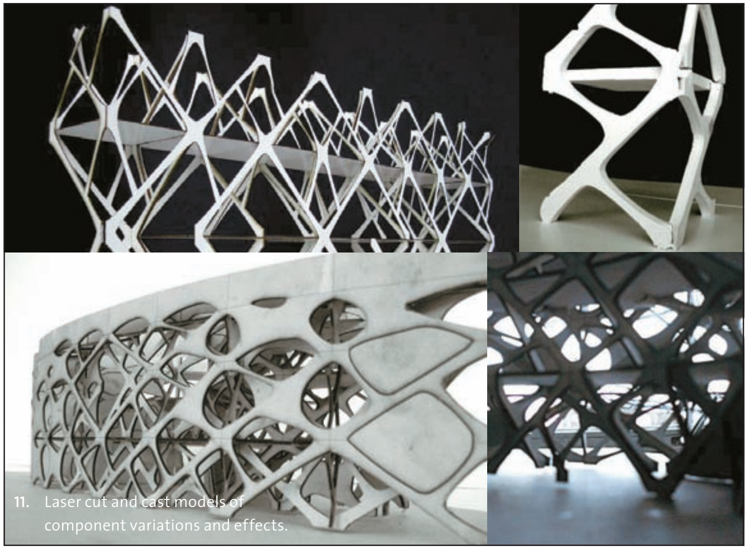


8. Global variations of component .



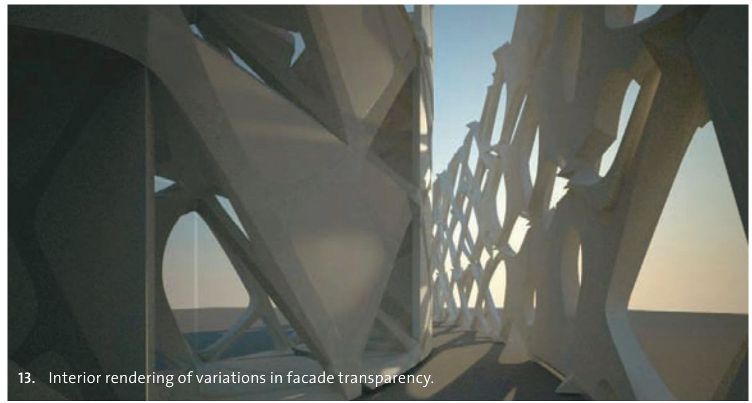
9. Local variations of component.

10. Laser cut models of Boolean massing principle.



11. Laser cut and cast models of component variations and effects.

12. Exterior rendering of variations in facade transparency.



13. Interior rendering of variations in facade transparency.

Projects Postscript

The extensive presentation of projects in this book is aimed at discussing and communicating the intentions, explorations and resulting proposals of the work. The material is not conclusive, in the sense of providing complete instructions for how to design similar projects, proof to validate them or generic truths based on their development. Instead I hope to provide a insights into otherwise hidden processes, in order to make them open to reflection, discussion, appropriation and continued study. To me as an architect, designer and researcher, this designates the most interesting territory for discourse, a conversation over the inner workings of design development, how it is affected by different agendas and intentions, and how advanced use of techniques and technologies is actively deployed. The design environments for the presented projects have been controlled, in analogy of scientific milieus of experiments. The projects have hereby been allowed to be formed without the immediate demand for useful implementations. As I revisited them during the development of this thesis, I realized many hidden potentials, which in some cases led to the complete redevelopment of parts of the projects in separate design loops, in essence making them all open-ended. In many cases, they are assemblies for different interests and approaches that can support each other and gain momentum and integrity, which in turn make them readable as design projects. In other cases, they are collaborative developments in which the topics covered here are just a part. They are vehicles for exploration, but may very well gain enough capacity to bridge the gap into real life, as products on the market, designed parts of buildings, or perhaps design and fabrication principles that can be employed elsewhere. In many cases, they are only partially operational in regards to integrated responsive technologies and applied production means. For the purposes of the research that is completed within this dissertation, they have shown that the notion of the prototype can be a useful concept in varying contexts, and is applicable to other experimental design fields, as well as research methods.

In the majority of the work included in the Projects book, I have been a co-designer. Since the designer often is completely immersed in the process during the project development, the work with this thesis has allowed me a certain distance to the work, which to me makes it eligible as subject matter for evaluation. The Projects book also features student work, and being a tutor in a design course that has been custom designed for a particular field of research can be extremely rewarding. The student projects presented are all the result of collective work, making use of the techniques and concepts explored in this thesis, but definitely also adding the individual interests of all collaborating parties. In a time in which the digitally based design within architecture is both proliferating and becoming part of specific sub-discourses, the work of the students is vital in that it may cross boundaries the designers are not aware of.

As a parametric construct, the prototype can be set up as a design system, which is inherently different from the fixed and definite proposal, and also puts new demands on its designer/developer. In analogue with the ideas of Deleuze and Cache, as instantiated in the notion of the ***objectile*** ↓ [P.18], the prototype entails a design environment of variation and differentiation within a defined solution space. When associated with ***fabrication techniques*** ↓ [P.28], it can encompass the limits of these techniques as an additional dimension of this space. As an extension, a prototype integrated with a ***Building Information Model*** ↓ [P.20] in a way that combines the innovative potential of a parametric prototype with the standards of protocol and links to logistics and production of a BIM may be a way forward that could ensure architectural innovation, while acknowledging the need for formalized and rational processes according to contemporary benchmark goals. The parametric system can be regarded as a device that enables ***design exploration*** **↓** [P.16], a concept that suggests that there is a territory to explore. The abstract notion of the design solution space can be defined and developed by a designer familiar with appropriate software tools. The variations of potential solutions can then be investigated through direct parameter input, ***parameter spreadsheets*** **←** [P.40] or other control mechanisms, such as the law curves integral to GenerativeComponents. Collaborating designers and other parties need to understand the rules and constraints behind the design system to certain extents, or at least produce many variants to map and understand the nature of the system. If the design system is equipped with intuitive controls and experiential effects, the design environments may introduce other ways of evaluating the potential solutions, as well as entice multiple users to explore potential designs in a play-like manner. Such environments could potentially allow ***non-designers to participate in formal design development*** **←** [P.86], with specific experiential interfaces custom designed for different categories of users.

The revisited projects were allowed to unfold into particular design loops that, while not meant to compete with and thereby disable the effect of the previous projects, re-open the design process and make new evaluation possible. The ***P5PARCEL Parametric Solution Space and Fabrication design loop*** **←** [P.36] made good use of the existing design configuration, and unfolded the hidden potential for a design solution space. The ***SG3SplineGraftRefit design loop*** **←** [P.80] explored an alternative solution for the structural rack developed previously. They use the existing project as a context in order to develop other variants that expand the scope of the project. There are further potentials already being considered. The fabrication principles developed in PARCEL could well be combined with the original production method after the recombination of different design instances proved possible. Instead of 1x6 units, there could be 125x6 units, to use the number of instances tested in the parameter spreadsheet. The conventional ***die cut tools*** **←** [P.35] could be produced at low cost. If all of the 125 variants would be mass-produced, enabling a virtually limitless reconfiguration of panel combinations based on the PARCEL concept. Of course, a more interesting route may be to develop a reconfigurable die cut tool, in which the steel blades themselves acquire the spline characteristics of the initial curve. The SplineGraft Refit project is still being developed, and a physical prototype has yet to be fabricated. Many issues will arise in this work, and the integration of a new actuating system is a considerable development in itself, requiring many resources to achieve a fully functional system. On the other hand, the design loop may continue as a separate structural project, with the manufacturing principle as a basis, as flat panels are folded into space frames. In addition to the possible routes out of the secluded design environment in which many of these projects were conceived, these projects and others like them will hopefully discover a continued existence within academic research milieus. The integration of techniques and technologies at all levels of development, and the exploration of the effects of new means of design and production, make them close to high-tech arts and crafts in certain respects. The discourse and in-depth documentation derived from them make them a strange combination of design and art, with purposes beyond the immediately understandable. The reframing process of this dissertation in itself has been part of another project, the search for means to communicate and disseminate results from design projects like this. The cross-reading (and the cross-writing) of this thesis has provided new constellations of the ideas discovered in theory references, as well as in the experience of project development. The definitions of ***models given by UN Studio*** **↓** [P.15], as carriers of knowledge and intelligence from one project to another, are similar to the definitions of the ***prototype given by Foreign Office Architects*** **↓** [P.26], which suggest that the prototype could be a mediator between different projects by reusing them as starting points in different situations.

This ambition of basing the development of a practice or at least a continuous registration of its mode of operation on the notion of prototypes, suggests the need for process modeling and a deeper understanding of the operations surrounding the prototype. The project descriptions suggest instrumental, operational and specific explorations of techniques, practices and effects. The definitions and investigations of important concepts and techniques, as defined by others, expand the understanding of these approaches. The overview of discourses of practice acknowledges the importance of a continuous debate on motivations and effects of architectural agencies. All in all, the different parts of this thesis as documented in the Contexts book and the Projects book prepare the way for future practice in research in these overlapping fields of interest.

Software

Adobe Systems, www.adobe.com
After Effects 6.5, Dreamweaver MX, Illustrator CS2, InDesign CS2, Photoshop CS2

ASGvis, www.asgvis.com
V-Ray for Rhino v4 SR1

Autodesk, www.autodesk.com
Autodesk 3Ds Max 7

Bentley Systems, www.bentley.com
GenerativeComponents v.08.09.04.76,
Microstation v8 XM v.08.09.04.51

Dassault Systemes, www.3Ds.com
Virtools Dev 2.0

Microsoft, www.microsoft.com
Office Excel 2007, Office Word 2007

Next Limit technologies, www.maxwellrender.com
Maxwell Render for Rhino 1.0.0.0

www.processing.org
Processing

Robert McNeel & Associates, www.rhino3D.com
Rhinoceros 4.0

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