

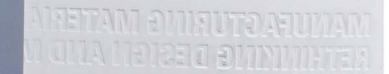
Architecture as a material practice implies that making – the close engagement of material – is intrinsic to design process. Making is increasingly being mediated through information that directs machines to shape materials and modify their properties. Innovative new techniques based on digital technologies are redefining the relationship between design and fabrication, enabling material explorations from the earliest stages of design and throughout the production process.

As a consequence, material effects, such as pattern, texture, relief, or varied properties, are becoming more customary in contemporary architecture as a means to manifest design intent on building surfaces. As surfaces become more complex in their form, shape, composition, and appearance, the manufacturing of material effects becomes a locus of design and production efforts.

Manufacturing Material Effects features the design and research work by some of the leading designers, makers, and thinkers today. The book presents:

- Emerging collaborative design and production practices based on innovative and experimental processes of material exploration
- New forms of architectural production
- Various computationally numerically controlled (CNC) processes of shaping and reshaping which enable designers to craft material effects
- Theoretical positions from all stages of the design and production process

This highly illustrated volume brings together a wealth of information and numerous examples from contemporary practice. It forms a useful guide for both students and practitioners interested in the design, development, fabrication, and assembly of highly intricate projects that are grounded in innovative explorations of both 'old' and 'new' materials.



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COMPUTATION AND MATERIALITY

MARTA MALÉ-ALEMANY AND JOSÉ PEDRO SOUSA / ReD Due to its physical nature, architecture has a strong relationship with the realm of materials. Architects have always been concerned with finding the appropriate material solutions to realize the production of built objects. In ancient times, materials such as stone or wood were used in the same state they were found in nature. Progressively, with the development of tools and processing technologies, humans learned how to adapt materials to better suit constructive solutions. Raw materials could not only be cut, shaped and assembled in more efficient ways, but they could also be combined to produce new materials:

Today, after steel, glass and concrete have notably expanded the building construction possibilities over the past 150 years, we are witnessing the emergence of an immense range of new composite and artificially designed materials, which promises to overcome the limitations of traditional materials. New technologies in engineering and science are defining our present condition, in which architects are consuming more materials, both in quantity and diversification, than in any other period in history. Nowadays, innovation has become a buzzword in the field, and this clearly illustrates the race for novelty that is moving design teams and attracting more clients to architecture.

When Vitruvius, in his influential The Ten Books of Architecture, declared the three essential qualities of architecture - firmitas, utilitas and venustas - there was an implicit understanding of materiality beyond its physical properties and corresponding structural performance. Following these premises, buildings had to stand firmly upright, but they also ought to look firm. Furthermore, they had to fulfill the requirement of beauty, which was an intangible quality. Thus, besides their structural integrity. materials had to address certain additional effects, some of which lay in the realm of poetics and symbolism. This is still true today, as architects continue to build with materials, while constructing intellectual discourses about their application. Perhaps more than in other disciplines, material selection in architecture tends to occur by evaluating a diverse set of performances resulting from physical and mechanical behavior, assembly methods, structural logics, environmental and economic constraints,

aesthetic and symbolic assumptions, or historical and contextual concerns.

During the 1980s, when digital technology started to be widely used in practice, the traditional relationship between architecture and materiality seemed to be threatened. This fact was perceived by many, and was widely discussed both in academic and professional environments. The emergence of a new tool (the computer) and a new medium (the digital) to develop architectural projects prompted a natural resistance from those who were deeply tied to conventional representation techniques. Although this reaction is understandable, the discrepancy between the ability to describe any imaginable geometry in the computer, and the limited building methods of that time to execute complex forms did not help in facilitating the cultural assimilation of digital technologies in practice. As became more evident during the 1990s, architects foresaw the possibility of new material effects emerging from alternative digitally-designed forms, but they could not find the means to realize them physically.

Since then, the progressive integration of computeraided design, engineering, and manufacturing (CAD/CAE/ CAM) systems and computer numerically controlled (CNC) production has changed the speculative nature of many digital design explorations. These technologies, transferred from other disciplines, allow the design, analysis, and fabrication of customized material geometries and properties. Besides the possibility of making physical artefacts out of digital information, materiality can also be reverse-engineered into digital media through scanning techniques. Thus, a total cycle of material development in architecture can now occur within a dynamic interplay between digital information and physical prototyping. A material system can be digitally crafted to achieve particular design goals. In that manner, geometric complexity and component variation can be instrumentalized, not solely for aesthetic purposes, but also to achieve more efficient building solutions. Freed from standardization constraints, material innovation may emerge from these processes, revealing surprising effects. As a result, for those architects committed to traditional representation techniques. this new digital condition has changed their perspective on computer technologies.

11.1a-b.
Digital craft: with CAD/CAM technologies, design can be extended into the fabrication process, as in traditional craft-based modes of production.

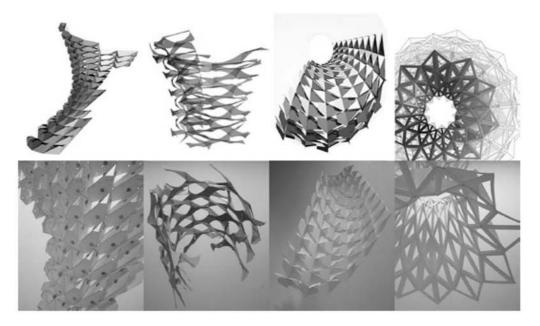
For ReD, with studios in Porto, Portugal, and Barcelona, Spain, the close link to materiality established by CAD/ CAM systems has been the key factor in granting computers a central role in the development of architectural projects. For that reason, the office established itself as a research and design practice in architecture and digital technologies. Despite the fascination of the virtual possibilities unveiled by these technologies, we are critical of discourses that radicalize their impact on architectural design. Instead of supporting a vision of rupture, ReD sees the influence of these technologies in practice within the logics of extension and expansion (figures 11.1a-b), where rethinking and re-using become strategies as valid as invention or discovery in a digital design approach. With this understanding, traditional conceptual and material possibilities are simultaneously taken into account with



new digitally-enabled ones, thus opening up a wider world of design opportunities.

Being involved in academia, through teaching and research, has been extremely important for the development of our practice. Due to its nature, academia is a privileged space for investigation and information exchange, often transcending the boundaries of the architectural discipline. In the past four years, *ReD* principals have conducted several design studios, seminars, workshops, and advanced research projects to explore alternative design opportunities emerging from the integrated use of CAD/CAM technologies (figures 11.02a—h). Associative and parametric design, scripting and programming, CNC machining and rapid

11.02a-h.
Non-standard
structures made
out of variable
components, conceived
and fabricated
using CAD/CAM
parametric modeling
processes (seminar
at the *University*of *Pennsylvania*,
Philadelphia, 2005).



prototyping are some of the techniques that have been used to investigate how computation can influence the development of building materials, components, and structures, in ways that would be difficult to achieve without these enabling technologies (figures 11.03a–p).

These academic projects have natural repercussions in *ReD's* practice. Without refusing the value of speculative digital explorations, the studio is deeply committed to the physical manifestation of its designs and technological investigations. The ultimate challenge lies in "real" problems and constraints. Understanding production as a creative endeavor, fabrication is engaged in early stages of the design process to avoid losing important creative opportunities. Throughout its working trajectory, *ReD* has interrogated a range of production techniques and materials, such as concrete, acrylic, wood, foam, plastics, and cork.

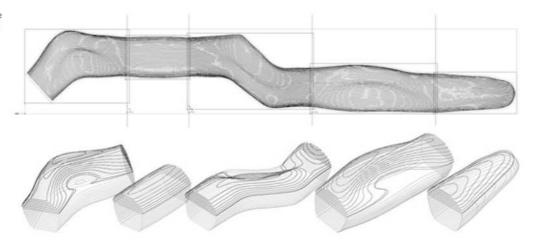
The following descriptions of four projects illustrate ideas and processes fundamental to our practice. In XURRET System, we explored the

production of formally complex and ornamented elements in concrete, while investigating the use of CAD/CAM associative parametric models to address the formal adjustments required by design and industrial partners. MORSlide, a project of variable panels fabricated entirely by our office, gave us the possibility to capitalize on the material effects of milled plywood emerging from 1:1 scale tests, thus making the fabrication process central to our design endeavor. In DRAGORAMA, we explored similar possibilities to produce textured variable panels in acrylic, and consolidated our mission of collaborating with other architectural practices to engage our digital design and fabrication expertise. Finally, the M-City project was an opportunity to expand our digital design methods by incorporating scripting techniques to resolve two large-scale installations in textile that explored variable geometries. Such an approach to the development of the project was necessary in order to address constant programmatic and economic fluctuations and the inevitable necessity of having to deal with several parties.

11.03a-p.
Re-thinking traditional materials using CAD/
CAM technologies: experiments with cork (PhD research at *Instituto Superior Tecnico*, Lisbon, with the support of FCT, Amorim, and Lasindustria, 2005).



11.04a-b. XURRET parts can be combined in any way, assuring a geometric continuity along the bench.



XURRET System

XURRET System is a seating structure or bench, originally designed by architects Ábalos & Herreros (A&H) for the Barcelona 2004 Forum and produced by the concrete company ESCOFET, S.A. Due to the formal complexity and ornamental intricacy of the design concept, two problems immediately emerged for the designers and the manufacturers. On the design side, there was a need to capture and test the project's intentions with an accurate digital model; yet, on the fabrication side, it became evident that traditional production processes would not be able to address the creative objectives of the project. In this context, ReD was hired as a consultancy firm to invent and implement a digital production process linking design, development, and fabrication. In addition to bridging the architect's ideas into mass production, the studio also collaborated in the final design.

As a system, XURRET consisted of five parts that had to be connected end-to-end in multiple ways, thus creating an array of seating combinations varying in length, orientation and overall shape. Given the original information from A&H, a series of variable two-dimensional sections and a basic three-dimensional model, we began modeling the bench as a smooth surface, carefully considering its future subdivision and

assembly (figures 11.04a-b). The geometry was designed to have the same section at the end of each part, whereas the surface tangency was controlled to match the curvature from part to part. As a result, any combination would always be perfectly continuous with the rest.

Besides the irregular form of the bench, the designers wanted to cover it with a filiform three-dimensional texture, taken from a leaf with extremely visible veins. They had designed this ornamental motif by repeatedly mapping the same leaf image all over the model. Instead, ReD proposed an alternative approach based on a system of tubular veins, crossing the end sections at specific controlled points. Form and ornament were engineered so that, regardless of the specific assortment of parts, the ensemble would always look both continuous and differentiated. This second approach seemed much more coherent with the combinatorial and organic nature of the project. Thus, ornamentation became a strategy to blur the boundaries between the parts, highlighting the assembly as a whole. In this process, the digital model was crucial to assure accurate tangency, guarantee the continuity of shape and texture, and extend this precision into fabrication.

Parametric design was used to develop an interactive process, which facilitated the design adjustments requested by either the designers or the concrete company. Based on the filiform ornamental concept, ReD developed a

11.05a-d. XURRET fillform texture: (a) parametric diagram of the fillform veins; (b) 3D vector mapping of the splines onto the bench surface; (c) 3D generation of the veins with swept tubes; (d) final 3D model.

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11.06a-b.

XURRET: CNC fabrication of
the final prototype with the
vein texture, in high density
polyurethane foam.



parametric diagram of the veins with spline curves; control points located at the contact sections were constrained to ensure the tangency from part to part, while the rest could be manipulated freely to adjust the curvature and density of the ensemble. This pattern was then vector-mapped onto the bench surface, and the resulting three-dimensional curves were used as extrusion paths to sweep parametric circular sections. Linking the spline diagram with the overall topology generated an adjustable model of the overall bench surface and the extent of the veins protuberance from the surface (figures 11.05a–d). This associative definition of the geometry supported the generation of multiple versions of the project, enabling the exploration of different solutions and providing immediate evaluation of the results.

As part of the consultancy, *ReD* took charge of the CAD/CAM production of two prototypes of the bench. The first one was required by the concrete company to understand the scale of the bench and check its functionality and comfort. Made of *Styrofoam* and purely volumetric, it was quickly produced by milling only the top of each part and completing it with simple sections at the bottom. The second prototype, in high-density foam, was milled using a 5-axis CNC machine to detail the vein texture over the entire form (figures 11.06a-b). This final version, which took much longer to execute, was used to extract the molds for the mass production of the *XURRET* parts in concrete (figure 11.07).

11.07.

XURRET: more than 20 benches have been installed in different configurations in the park of the Barcelona Forum.



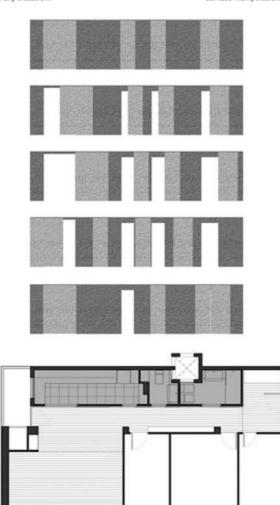
11.08. XURRET's organic concrete: the complex curvature and intricate surface veins perfectly match at the contact sections.



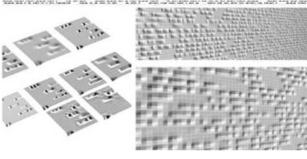
For ReD, the value of this experience was manifold. Besides its significance as a successful collaboration between architectural practices and manufacturers, the XURRET project exemplified a process from virtual data to material product, with a digital methodology for evaluating the design and the capacity to test it at full scale. The possibility to digitally fabricate an early 1:1 scale prototype of the bench was a key moment in the development process. Indeed, it was decisive to instill confidence in all parties in the project, where structure and surface, volume and texture, form and ornament ought to be delicately blended (figure 11.08). Finally, the mass production of large, heavy, and monolithic elements in concrete revealed a much broader interest for ReD. The scale of this project (and in particular the weight and dimensions) definitely exceeded the scale of furniture design to achieve that of an architectural building.

11.09. MORSlide: the surface pattern takes into account all possible positions of the sliding panels to achieve continuity in any situation.

11.10a-d. MORSlide: Morsecoded text was used as a graphic device to develop a set of digital surface manipulations.







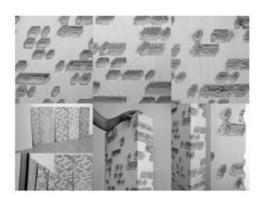
MORSlide

After the XURRET system, in 2005 ReD did the interior renovation of an apartment in Barcelona, focusing on maximizing the common space to stimulate a new living experience. Reflecting on issues of scale and functionality, ReD's design proposal focused on wrapping the wet core (kitchen and bathrooms) with a single material surface. For this purpose, MORSlide was developed as a system of wall panels and sliding doors in plywood, which, by hiding the spaces behind it, created a large box with a unique skin effect. Visible from everywhere, it turned into the most significant design element, offering a suggestive opportunity for ornamental exploration (figure 11.09).

To emphasize the overall continuity, the existing doors were replaced with sliding doors, with the aim of unifying the plane of ornamentation. The next step was to find a decorative motif that could blur the vertical joints between the panels of the box, while taking into account all possible positions of the sliding doors. Morse code emerged as the most promising visual pattern, with simple abstract symbols and few rules of composition. Its three elements - dash, dot, and space - offered endless combinatorial possibilities. Beyond the representation of meaning, a Morse-coded text constructs graphic patterns that are horizontal, generating a complex, randomly distributed field. Furthermore, the superimposition of a piece of text over another does not affect its overall appearance as a motif of dots and dashes, a crucial aspect when considering the mobility of the sliding doors.

11.11a-i.

MORSlide: material exploration.



11.13a-b.

MORSlide: the eroded corner; view from the entrance.



11.12. MORSlide: interior view of the apartment; the kitchen is hidden behind the panels.



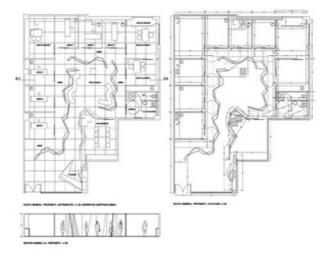
Going beyond the simple mimic of its pattern, Morse code was used as a graphic device to create a three-dimensional surface expression (figures 11.10a-d). Departing from the image of a coded field, the project evolved through several studies of surface curvature manipulations, with simultaneous assessment of their material effects through the CAD/CAM production of physical prototypes. The CNC milling of the plywood panels was fundamental because the machining parameters dramatically influenced the material effects resulting from the same digital source. As different tools and alternative milling trajectories produced very different engravings (figures 11.11a-i), material prototyping became an integral part of the design process. The production of milled samples early in the process suggested various design avenues; the creative process could no longer be detached from the experience of fabrication. In the end, the use of CAD/CAM technologies supported the production of seventeen differentiated textured panels.

A particularly successful aspect of MORSlide can be observed in the overall field effect that helps to hide the joints between panels. The plywood skin presents a continuity that still exists when displacing the sliding doors (figure 11.12). In addition, its eroded effect produces appealing light reflections that vary during the day. The corner of the box presents what is probably the greatest effect, which is visible from the entrance (figures 11.13a-b). There, the precision attained with digital fabrication tools is unmistakable: the texture perfectly continues despite the 90° angle at which the two surfaces meet; the corner edge - no longer a vertical line - presents an intricate (eroded) intersection curve, resulting from the milling process on both sides. More importantly, MORSlide produces a perception of a larger space, enriched by the scenographic quality of its plywood panels, which was its intended material effect.

MORSlide explores the potential of the interaction between computational design tools and material fabrication qualities to support emergence of additional creative opportunities. Its final material effects can only be understood by recognizing three equally important factors: digital geometry, machining parameters, and material properties. One can identify all three by looking at the panels: the three-dimensional surface from the computer, traces of the milling tool, and the emergent colored rings from the laminated composition of the plywood boards. MORSlide shows that traditionally distant poles of design and fabrication can fluidly be merged through extensive use of digital technologies, approximately relating our experience to the crafts production.

11.14a-b.

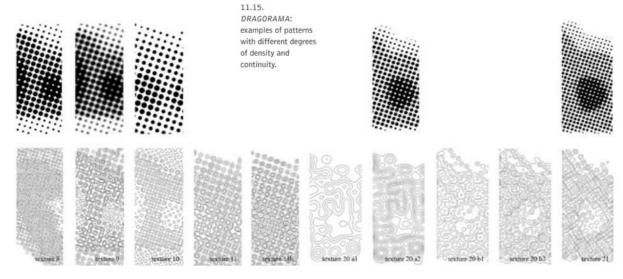
DRAGORAMA: plan of the Chinese medical center and layout of the folding screen.



DRAGORAMA

DRAGORAMA was done in collaboration with the firm Habitat Actual Arquitectura of Barcelona. ReD was invited as a consultancy firm to develop a partition for the interior renovation of a Chinese medicine center. The designers had developed a simple scheme, placing the doctor's offices along the perimeter of the space and leaving an empty central waiting area, easily accessible from the entrance reception. A lightweight partition, like a folded origami screen, separated the offices from the central space, creating a private corridor to connect all of them. Extending towards the entrance, this screening surface also conducted the patients from the reception to the waiting area (figures 11.14a—b).

ReD developed the DRAGORAMA partition as a continuous surface. Its constituent panels, which had different sizes in accordance to their varied spatial orientations, were done in acrylic and decorated with a customized engraved pattern. As a way of contextualizing the project, ReD proposed a pattern that indexed the distance between the folding screen and the doors of the offices: by increasing the pattern's density according to proximity, the final engraving would offer a play between translucency and opacity. In that manner, the partition would present not only an interesting material effect, but also act as a functional screen to hide the doors along the corridor.



11.16a-g.

DRAGORAMA: CNC
engraving of the patterns on
translucent acrylic panels,
followed by laser-cutting the
panels' contours.



The specific texture of the DRAGORAMA screen was generated by determining areas of the partition that were closer to the doctors' offices and finding the intersection between a series of virtual spheres located at the center of each entry door and the surface of the partition. By unfolding the screen, the resulting intersections created an instrumental gradient map of proximities. Using this diagram, ReD generated several graphic motifs (figure 11.15), and selected one that presented enough regularity to emphasize the screen's continuity, while including simultaneously the desired performance-based density variations.

To assess the material effects of engraving the patterns on acrylic, full-scale samples were fabricated using a CNC milling machine. For the final production, the *DRAGORAMA* panels were produced by milling the ornamental motif on standard acrylic sheets, followed by a secondary process of laser-cutting the panels' particular contours (figures 11.16a–g).

Once installed on-site, *DRAGORAMA* produces delicate spatial and material effects, as its milled texture becomes visible to different extents under changing light conditions. When someone walks along the corridor, the perception of the continuous ornamental pattern is greatly enhanced (figure 11.17), because the engraved lines are revealed when someone stands right behind the panels, obstructing the light. (figure 11.18).



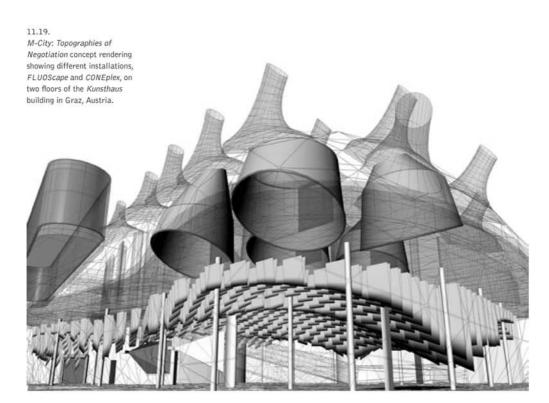


M-City

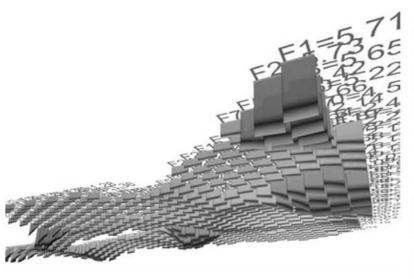
In 2006, the design of the installation for the M-City exhibition at the Kunsthaus in Graz, Austria, presented ReD with a double challenge, due to the unique singularity of the building and the scale and heterogeneity of the event's program. Unlike traditional museums, the Kunsthaus is an art institution that has no permanent collection. The building is an empty container without divisions, in which every venue is built from scratch with a new formal manifestation. Previous exhibitions have either used standard modular walls to subdivide the space and organize visitor circulation, or relied on the construction of completely autonomous installations with an inherent structure and morphology. However, both strategies, whether anonymous or selfreferential, lack a direct relationship to the building. By contrast, ReD's intervention sought to activate the

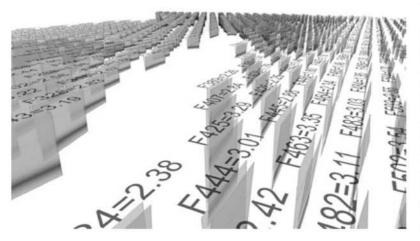
singular conditions of the building, creating an interface between the exhibited works, the visitors, and the building's particular context.

The M-City exhibition examined emergent urban landscapes in average European cities, and was divided into two main curatorial subjects — Urban Themes and City Portraits. While the former was broken down into six subsections (Earthscapes, Eurosprawl, Mapping, Migrations, No Vision?, and Shopping), the latter consisted of six video projections based on the European cities of Basel, Krakow, Graz, Ljubljana, Ruhrstadt, and Trieste. M-City combines 30 artists in this dense programmatic organization, with works that included models, videos, photographs, paintings, and installations. The list of works changed constantly during the development of the project, thus requiring a design process sufficiently flexible to accommodate such changes without compromising the general design intentions. As in the



11.20. M-City: the FLUOSoft script creates a three-dimensional model for each of the 587 different "flags" with labels and surface areas.





previous projects, ReD explored parametric and generative digital processes to assist both design and manufacturing. This digitally integrated approach provided the needed flexibility to deal with program and budget fluctuations, while simultaneously facilitating the negotiations among architects, curators, artists, and fabricators.

ReD's first intention was to interact with the existing building as much as possible. In order to reflect its singular qualities, an intervention in the Kunsthaus interior ought to be necessarily different than one inside a conventional museum. At Kunsthaus, the lighting systems on both floors were so striking, that they provided a departure point for the project's development. The design concept aimed at generating a "response" from the ceiling to the artwork beneath. By controlling the light and suggesting various circulation paths, the intervention became an interface between the exhibition content and the building. Although this concept was applied to both floors, their spatial differences suggested two formally distinct installations: FLUOScape on the first floor and CONEplex on the second (figure 11.19).

On the first floor, the excessive, monotonous grid of 587 fluorescent lights provided the basic infrastructure to generate a completely new spatial effect. By fixing a soft cover (a flag) of varying lengths to each fluorescent light, the flatness of the ceiling was transformed into an inverted topography that would flow over the entire space dedicated to the exhibition themes. This topography of flags, with their differing lengths related to the works exhibited below, suggested gathering areas and new circulation paths without using any conventional walls or corridors.

Several modeling techniques and alternative software solutions were tested to generate this topography and were then rejected as insufficiently flexible and precise. We had to develop our own "design tool" to generate and interactively control the ceiling topography: FLUOSoft is a customized script written in AutoLISP, which merges design, analysis and fabrication. The script was written to manage an infinite number of "flags:" for each light, it calculates the relative distance to the center of each thematic area, evaluates neighboring conditions, and determines the flag length according to curvature parameters. The script constructs a three-dimensional model of each flag, draws a flattened duplicate in the XY plane with a contour line for lasercutting, computes its surface area to provide an accurate (and immediate) overall material (and cost) calculation, and automatically generates an individual label to be engraved or printed onto the flag for installation (figure 11.20).

11.21a-d.
FLUOScape was fabricated in Germany with a large-scale CNC laser-cutter normally used in the production of boat sails.

11.23. FLUOScape: the ceiling as a soft response; a cupola-like form is created above each thematic area by progressively varying the flag lengths.





Despite the geometric complexity of the final topography, the flexibility of the design process allowed changes to be incorporated right up to the fabrication deadline. Different alternatives were quickly produced and evaluated, providing immediate aesthetic, functional, and financial feedback, without compromising the overall design intentions. At the end of this entirely digital process, the "flags" were laser-cut in Germany from white translucent voile by directly following the patterns generated by the FLUOSoft script (figures 11.21a-d). The scripting-based process enabled a fully nonstandard production with full-scale prototyping and on-site material testing. The 587 flags were installed over three days at the Kunsthaus, using a simple system for attachment to the support structure for the lights. Despite the large number of elements, the positioning in the space was simplified by the FLUOSoft-generated labels, matching each flag to its corresponding fluorescent light (figures 11.22 and 11.23).

The second-floor installation entailed the creation of six "projection environments" displaying video "portraits" of six cities. The curved ceiling and lighting – now large skylights with circular fluorescent lights – were the most striking spatial features for exploration. To avoid conventional enclosed, orthogonal rooms, we designed lightweight, conical elements that were suspended from the existing skylights. These intimate enclosures were gently tilted, without touching the ground, to invite visitors to gather beneath them and view the projections.



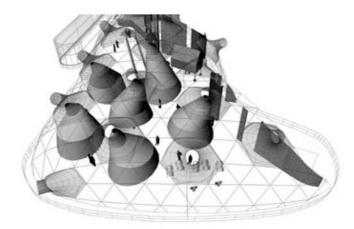
11.22. FLUOScape: view from the arrival ramp on the first floor of the Kunsthaus.

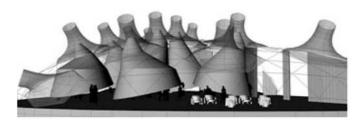
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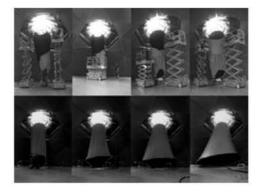
11.24. CONEplex: 3D model of the six projection cones at the top level of the Kunsthaus building.

11.26.

CONEplex in space, showing the strong relationship between the cones and the building context.







11.25a-h. CONEplex: installing the cones.



As on the first floor, the *CONEplex* installation avoided creating any linear or preconceived trajectory for the visitor. Each of the six cones was assembled from two parts that resulted from connecting three circular rings. While the bottom part was identical for all cones, the length of the top part was adjusted to absorb the variable ceiling height at each specific location. Because the cones were designed to be asymmetrical, the different rotation of each cone in relation to the others produced a formal configuration that gave an impression of six completely different cones (figure 11.24).

The cones were also fabricated in Germany using information extracted directly from the three-dimensional model. The textile skin was CNC-cut, the metal rings were CNC-bent, and a full-scale mock-up was assembled in the factory. The material for the cones - a double-sided stretchable Lycra - provided a double effect: the outer silver layer reflected the ambient light, while the inner black layer created enough darkness for the projections. Structurally, the Lycra layers support the metal rings, which were positioned in space using tension cables to achieve the designed configuration (figures 11.25a-h). The screens and projectors were hung from the middle rings, which were all positioned at 3.5 m above the floor to create a "horizon" that established yet another relationship with the context; perfectly aligned with the fourth-floor viewing balcony, this virtual plane highlighted the changing curvature of the ceiling (figures 11.26 and 11.27).

11.27.

CONEplex: suspended rooms;
without touching the ground, the
six cones define dark spaces for
projections while inviting visitors to
enter and stay underneath.



In developing a proposal that negotiates between the particular spatial conditions of the *Kunsthaus* and the specific programmatic requirements of the *M-City* exhibition, the use of digital technologies for design and fabrication was fundamental. The use of programming (scripting) enabled the conceptual and material exploration of customized elements by liberating the project from the standardization that still dominates the construction industry. The direct use of data from the

digital models to control CNC fabrication allowed highly precise production in a very short time. Moreover, this twofold condition facilitated the architectural process, allowing (despite many geographical barriers) a more interactive collaboration by all parties involved in the project.

As with the previous projects, the M-City exhibition provided a "real" context to test critical interests that the studio has been developing since its creation. Concerned with the exploration of the impact of digital technologies on the discipline of architecture, ReD's research and professional agenda are not tied to a singular digital design method or manufacturing technique. By expanding the design and fabrication know-how, the studio can augment the creative and productive strategies to efficiently fit the particularities of each design challenge. The four projects presented here clearly illustrate this vision. Different materials - concrete, wood, acrylic, textile, and metal - and their inherent potential to create particular effects were investigated using various digital modeling and scripting techniques, while interacting simultaneously with diverse CNC fabrication processes. In all cases, the association between computation and materiality allowed the crafting of particular production processes to attain unique design solutions.

APPENDIX AUTHOR BIOGRAPHIES PHOTO CREDITS INDEX



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David Lewis is a founding partner and principal of Lewis. Tsurumaki.Lewis (LTL), an architecture and research partnership based in New York City, dedicated to exploring the inventive possibilities of architecture through a close examination of the conventional and the overlooked.LTL Architects has received numerous awards and honors, including representing the USA at the 2004 Venice Architecture Biennale, participating in the Architectural League of New York's Emerging Voices lecture series, and being selected by Architectural Record as one of ten firms representing the vanguard in contemporary architecture in 2000.

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Co-founded by architects Marta Malé-Alemany and José Pedro Sousa in 2004, ReD | Research + Design is an award-winning research and design studio in architecture and digital technologies. Operating internationally from Porto and Barcelona, ReD merges research and design endeavors in both academia and professional practice. Specializing in implementing cutting-edge digital technologies to assist design conception, engineering and fabrication (CAD/CAE/CAM), ReD is committed to exploring the new design opportunities that emerge from the cultural and technological context of today's digital era. With built projects in the USA, Austria, Italy, Spain and Portugal, ReD's work has been presented regularly in lectures, selected for architecture exhibitions, and recognized in international publications. In 2006, ReD was the winner of the prestigious FEIDAD Award, and winner of the Portuguese prize in Ephemeral Architecture "Outros Mercados," In 2007, ReD received the NEOTEC grant from the Portuguese Agency for Innovation, to develop an entrepreneurial project with a technological basis.

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