the Design and Fabrication of innovative forms in a continuum

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deep surfaces - digital research and affective material conditions

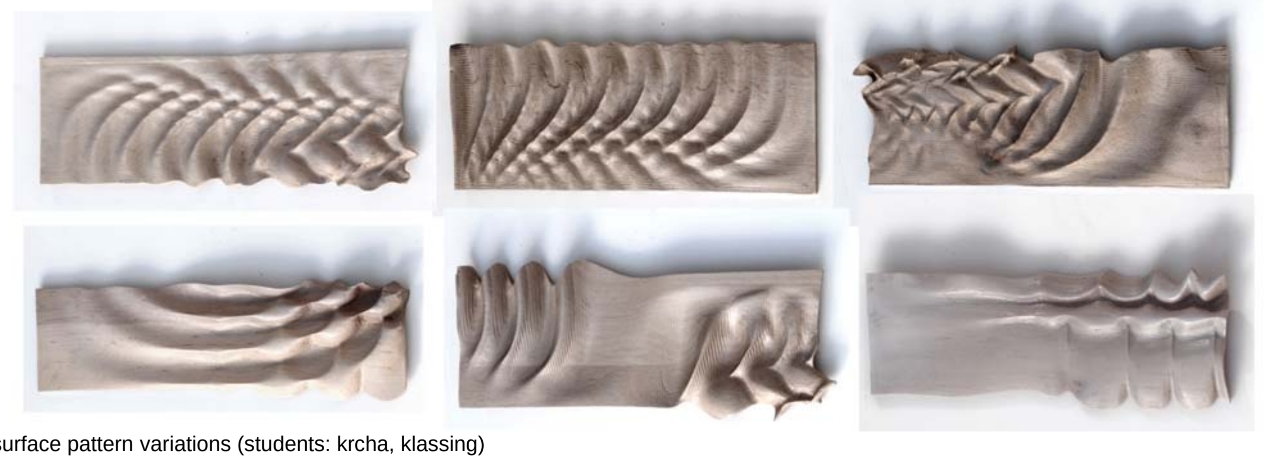
keywords: parametric design, digital design, script based design, design research, experimental architecture, interiorities, interior design, corian milling, laminated wood board milling.

This paper examines the results of this year's design research agenda, set up by Studio Hadid at the University of Applied Arts in Vienna. Students investigated into script based and parametric design research, shifting their focus from urban scale and building scale onto highly integrated multi-layered interior organisations. The paper documents the results of this research in the light of the current state of design theory and exemplifies its underlying strategies and processes by showcasing two particularly successful student projects, one examining milling technologies on pre-molded Corian sheets and one researching milling techniques for custom made laminated wood boards within their design research agenda.

Throughout the last years Studio Hadid has set its agenda on script based and parametric design research, aiming to explore new design methods in order to advance the field of contemporary digital architectural design. Students investigated into script based and parametric design research, shifting architectural design towards a new digital paradigm. During this time, a series of innovative design processes were iteratively developed, tested, improved and applied in different architectural scales, the urban scale, the building scale and the ergonomic scale.

Student work is organized in a “vertical studio”, in which students with different levels of experience work together on one project in self organizing teams of three or four students, complementing each other's individual skills. In this way previously acquired knowledge and techniques can be applied, redistributed and passed on among all participating students.
It is considered an important didactic aspect, that each student, according to their specific abilities and ambitions, can set out their own procedural method within the paradigm of parametricism. Whereas ambitious or advanced students might prefer to write their own code to achieve maximum control over the processes they set up, others might rather make us of parametric modeling tools, which are readily included in the software they use, like particle system simulations, fluent dynamics analyses or hair dynamics.
Script based design research, as practised in the studio, is therefore not limited to the technique of actually writing code, but is rather understood as systematic, rule based mode of operation, in which a process is analyzed and broken down into a series of smaller subsequent steps, that are – with varying parametric values - iteratively and thoroughly applied to all the entities within the fields to be structured.

As part of the studio culture, digital research and parametric design are closely linked to digital production techniques, setting up an iterative process in which the effects of lawful digital production are constantly evaluated and results are immediately fed back into the design process. The interdependencies and relations between script-based and analogue modeling lead to digital models on the one hand, and to the research of milling techniques, which produce a wide range of physical models on the other hand. Both together result in an advanced and complex architectural project.



surface pattern variations (students: krcha, klassing)

Devising an enclosed architectural space that holds the potential for a wide range of affective and effective conditions calls for the systematic elaboration of tectonic systems that unfold and differentiate within the terms of their own internal logic. This can be most clearly pursued by starting to investigating interior conditions, without immediately exposing the resulting architecture to external influences and conditions.

in this context the appropriation of complex recurring geometric patterns and their underlying mathematical concepts becomes a source for the experimental development of gradient architectural field patterns with different degrees of densities which in turn are able to produce a whole range of different affective architectural conditions.

The concepts and logics in question are mostly drawn from the domains of mathematics, physics or biology and include:

Dynamic systems: for example fluid dynamics or particle systems.
Crystallization systems: for example diffusion limited aggregation.
Self-optimizing systems: for example Voronoi patterns, foams and bubbles.
Geometric systems: for example triangulation systems or self-similar subdivisions.
Behavioural systems: for example flocking or swarming.

All these systems are to a certain extend characterized by the following properties:

Complexity: the system builds up complexity out of a series of single components. However, their interaction according to a set of clear rules and their initial condition give rise to a high level of complexity.

Emergence: the emergent properties of a system are generated by the recurring iteration and superimposition of interactions of its single components, which add up to the complex state of that system. Consequently, the result of such a non-linear process can due to its complexity not be predicted. This is also known as a "bottom-up" process, as opposed to a "top-down" process, in which the overall form is determined first.

Gradient transitions: a field is seen as one continuous organisational unit, which organises and modulates a series of entities, which are subjected to the same set of internal and external rules. As the parameters that drive these sets of rules vary gradually across the field, no binary conditions occur, rather gradient transitions from one state to another.

Coherence: due to their strictly rule-based generative process, resulting field conditions show a high level of coherence, not primarily (or only) in aesthetical terms, but rather in the sense that consistent conceptual and abstract logics necessarily become embedded into the system. A formal or visual coherence needs then to be understood as the result of such a process.

Modulated field conditions: a system is able to create a modulated field of different yet gradually changing densities and/or other properties that are held in a dynamic equilibrium. Emerging and receding patterns (of geometry) resulting from this system are always understood as modulations of an in itself continuous system of changing dependencies, where each modulation becomes an environmental condition (i.e. an agent of change) to their adjacent entities.

The systematic exploration and subsequent application of a system's emergent and non-linear behaviour gives rise to the emergence of unpredictable design patterns within the design process. At the same time this procedure evades traditional deterministic design approaches, which are mostly relying on previous experience and which are typical of the presently still predominating design paradigm of modernism. Research indicates, that arguably all successful intuitive decisions rely on previous experiences which are processed on a subconscious level. Therefore the more experience one has in a specific field, the better the intuition (Gladwell: 2005).
These modes of operation however are incapable of starting to shift the design processes towards a new paradigm, within which new organisational, typological or formal solutions to existing design problems can be developed. The production of knowledge mainly operates within its respective research paradigm developing its own set of tools after once having set its research agenda (Kuhn: 1967). This is also true for modernist architecture, where design methodologies and their modes of representation to a large extent foreclose possible design innovations.

All processes in question are evaluated according to their individual capacity to give rise to emergent solutions which bear relevance in an architectural context. As these generic processes in themselves have arguably no capacities to

solve problems outside their initial scientific domain, they need to be appropriated, enhanced and transferred into the field of architecture.
To this end the intrinsic properties of a generative process are analysed, abstracted and catalogued at first in order to be able to speculate about their potential to solve architectural problems. In a next step students try to understand and describe the process in a mathematical way, allowing them to reproduce its results in a scripted or parametric process. When transferring the process to architecture, students develop an architectural model, indicating which contextual internal and external requirements will then determine the values of the parameters that drive the emergence of these configurations.

The main objective is to identify processes, that can be efficiently utilised to purposefully structure, modulate and differentiate fields of varying scale. This is by nature a heuristic and teleological process, in which the qualities of the architectural results depend on the exhaustive and thorough exploration of a specific design space in order to maximize the effects and affects of the generated interior spaces. The systematic variation of intrinsic and extrinsic parametric values results in an immense range of possible outcome and determines the capacity of generating unexpected results and rising their morphogenetic potential, while at the same time testing the limits and boundaries of the conceived system.

"Only if virtual evolution can be used to explore a space rich enough so that all the possibilities cannot be considered in advance by the designer, only if what results shocks or at least surprises, can genetic algorithms be considered useful visualization tools." (de Landa: 2001: 521)

Interior spaces always require a concurrent series of complex design solutions, whereas most scripted systems cannot but produce one aspect of its underlying systematics and logics, which then guide the generation of project-specific geometries and shapes. Thus a series of different systems and subsystems need to be implemented into the project simultaneously, that all work together to generate the overall complexity of the tectonic system.

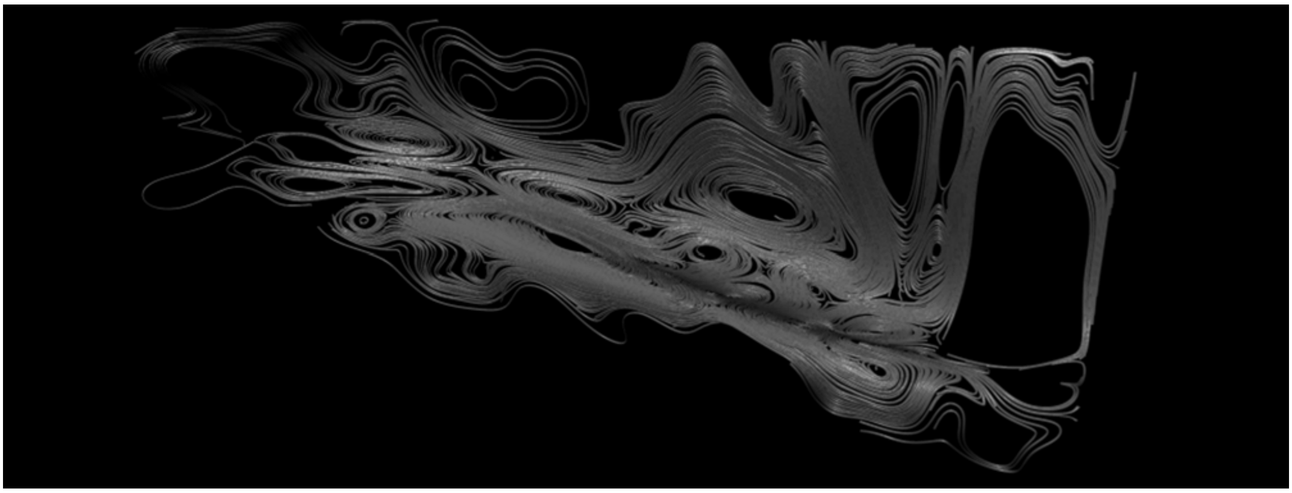
Students are aiming to build up a multi-layered complexity with a high degree of lawful differentiation within each system and with a high level of correlation between the various subsystems that constitute the overall tectonic system. Each subsystem is associated with corresponding or complementary differentiations within the other subsystems. For example, structural differentiation is correlated with material or textural differentiation etc.
the main focus rests on developing complex, layered and highly differentiated tectonic systems that then in turn can start to compete – and be compared - with the best historical examples in terms of their richness, coherency, precision of formal organisation and qualitative differentiation and the intensity of part to part and part to whole relationship.
As ordered complexity, these designs are highly differentiated, yet based on a systematic set of lawful correlations that are defined between the differentiated elements and subsystems. Just like natural systems, compositions are so highly integrated that they cannot be easily decomposed into independent elements. This constitutes a new kind of elegance, an elegance that articulates complexity.
Whereas one should avoid simple repetition of elements or the collaging of unrelated elements, all forms and formations developed need to be considered to be parametrically malleable in order to be differentiated gradually at varying rates and correlated systematically.

Considering (one more time following Kuhn) the recent shift from modernism (via its two transitional phases postmodernism and deconstructivism) to parametricism as a transgression into a new architectural paradigm, it becomes clear, that the studio's current agenda at this point, at which parametric design and its underlying loigics and techniques are about to become mainstream agenda, is not opening up a new architectural agenda or paradigm, but rather subjects parametric architecture to a series of refinements and sophistications while keeping on working within the same scientific paradigm and further advancing the field of parametric design.

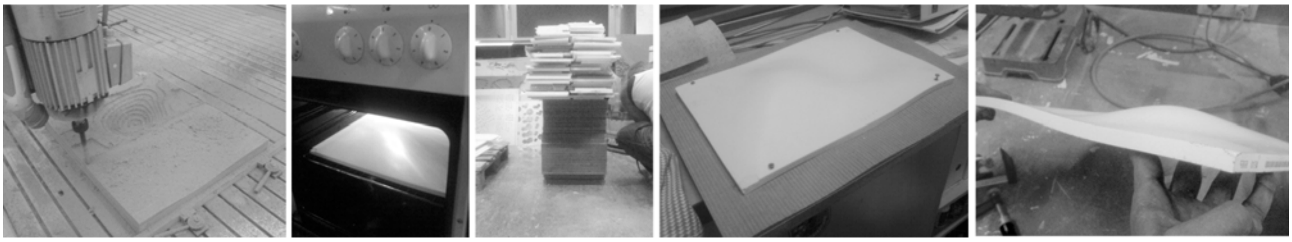
To facilitate and channel the design research towards a parametricist interiority, students were asked to work on the design of an urban club in New York. The design effort was focused on a cluster of primary social rooms as lounge room, dining room, library, conference room, ballroom or den.

In the course of this research, students started to investigate innovative methods of digital production in order to be able to produce adequate physical models that would help them to evaluate the effects and affects that were digitally conceived. The results of these model making experiments where then fed back in to the research cycle to further advance the project. the final design then is aimed to synthesise all of the aspects that contribute to a full-blown architectural experience, like form, structure, material, texture, ornament, colour, transparency/opacity and light/shadow.

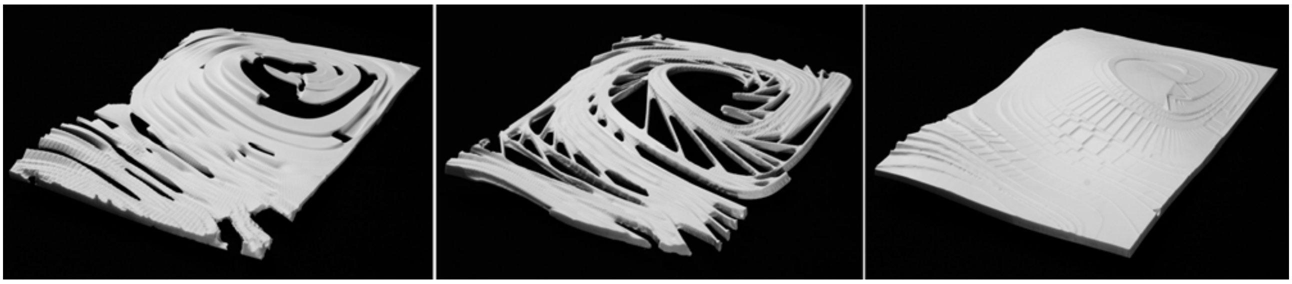
The project *Barotic* (students: Karaivanov, Guellmeister, Reist, Elbanero) explores dynamic systems, in seeing its potential of embedding an infinite amount of interior conditions within one parametric organisation without losing its overall coherency. By translating architectural elements into dynamical inputs, a three dimensional vector field system with a high degree of gradual differentiation and systematic correlation is constituted, which by far surmounts conventional collage techniques.
Streamline-Method is used to visualize the vector data. By controlling and manipulating the line output a fluent shift from texture to structure is achieved. In this way various architectonic elements with different functions, structures (facade, stairs), textures (floors, furniture) appear as iconic figurations within the system. Various subsystems express a structural differentiation which correlates with the material and textural differentiation.
As within this design process structures and textures are inscribed onto and interwoven into three dimensional surfaces, the students started, based on previous explorations, to explore new milling techniques by experimenting with the milling of three dimensional pre-moulded Corian sheets. In first experiments Corian sheets were manually deformed and pressed into pre-milled molds by heating them in an household oven. In a second step these formed sheets were then milled with different drillbits, inscribing patterns onto the moulded surface. Experiments show that the level of temperature the different drillbits reach when in operation facilitates the process of milling as it makes the material easily malleable.



barotic: digital model (students: Karaivanov, Guellmeister, Reist, Elbanero)

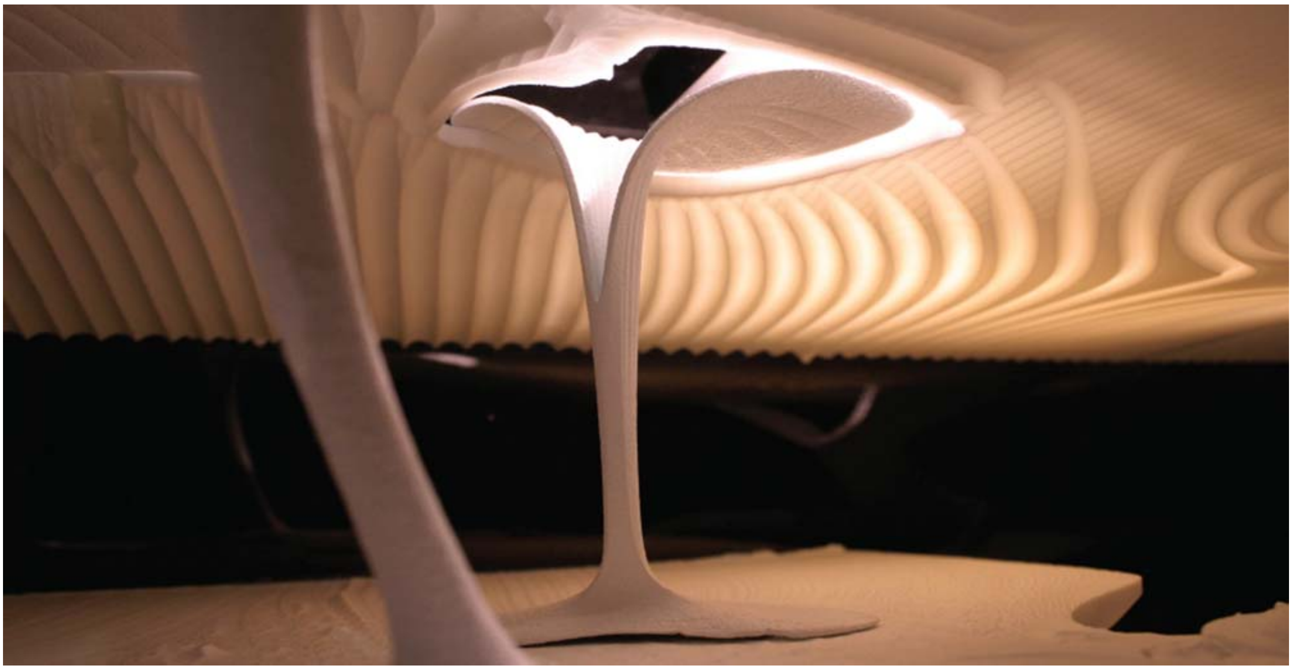


barotic: Corian moulding (students: Karaivanov, Guellmeister, Reist, Elbanero)



barotic: first test results (students: Karaivanov, Guellmeister, Reist, Elbanero)

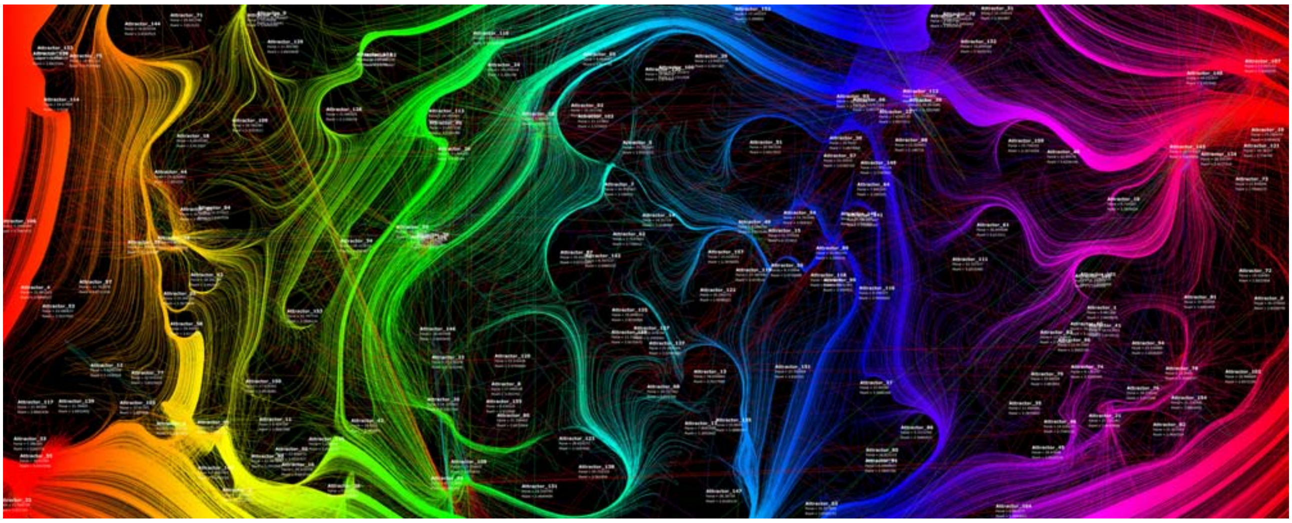
barotic: final model (students: Karaivanov, Guellmeister, Reist, Elbanero)



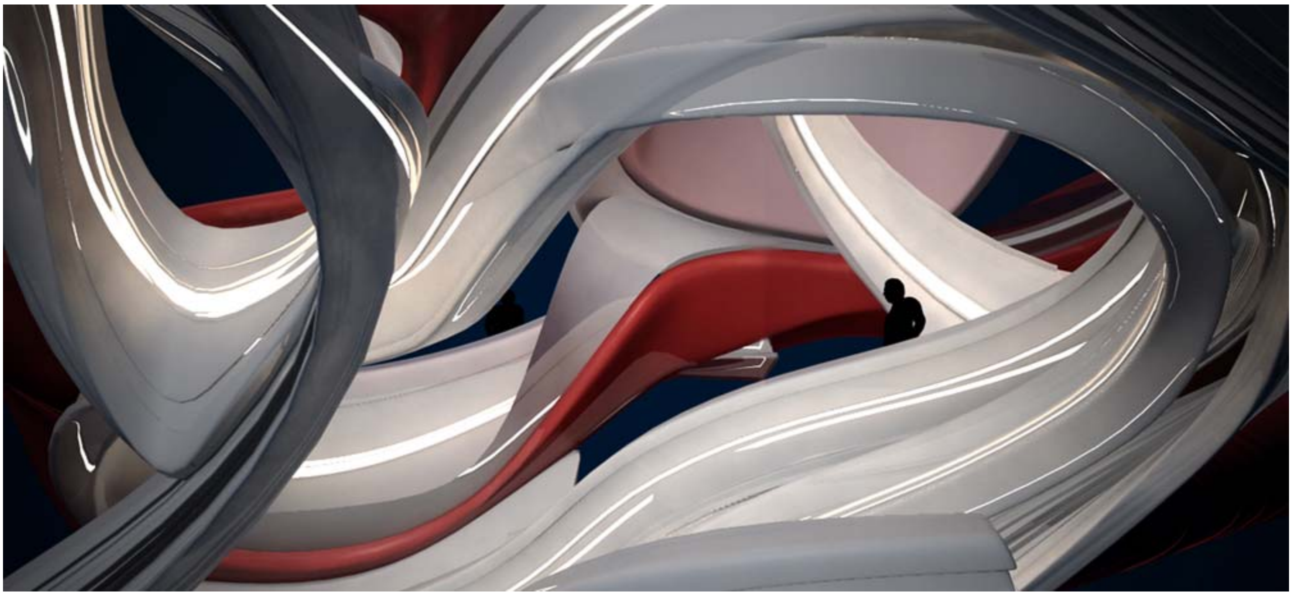
barotic: final model (students: Karaivanov, Guellmeister, Reist, Elbanero)

The project *Interiorities II* (students: Büyükköz, Kleindienst, Petrovic) starts with analyzing history's richest examples of architecture, from Versailles's landscape design and Isfahan's mosques interiors, to art nouveau furniture. During investigation it becomes clear that interior spaces are not reducible to a collage of its individual components, such as furniture, material, structure or ornament, but interiorities are rather constituted by a multitude of nested systems creating both visual and architectural complexity not by their separateness but through their interrelatedness. Therefore our primary research-interest lies in the "in-betweeness" of interiorities, the transition between one atmosphere to another, the overall coherency throughout several systems or spaces.

To achieve this, a basic field logic is developed, which - by negotiating between points of attraction - generates a primary intensity map of spatial differences. This data set was used to generate rough, diagrammatic spaces, which were further refined by secondary systems to create the building's components such as structure, apertures or façade. To create viable physical representations of the multilayered color-coded system created, the students started to experiment with the manual fabrication of different laminated wood boards, which were then milled with patterns of different directions and depths to test the resulting effective and affective conditions. The finished elements were then assembled to a coherent mixed media model.



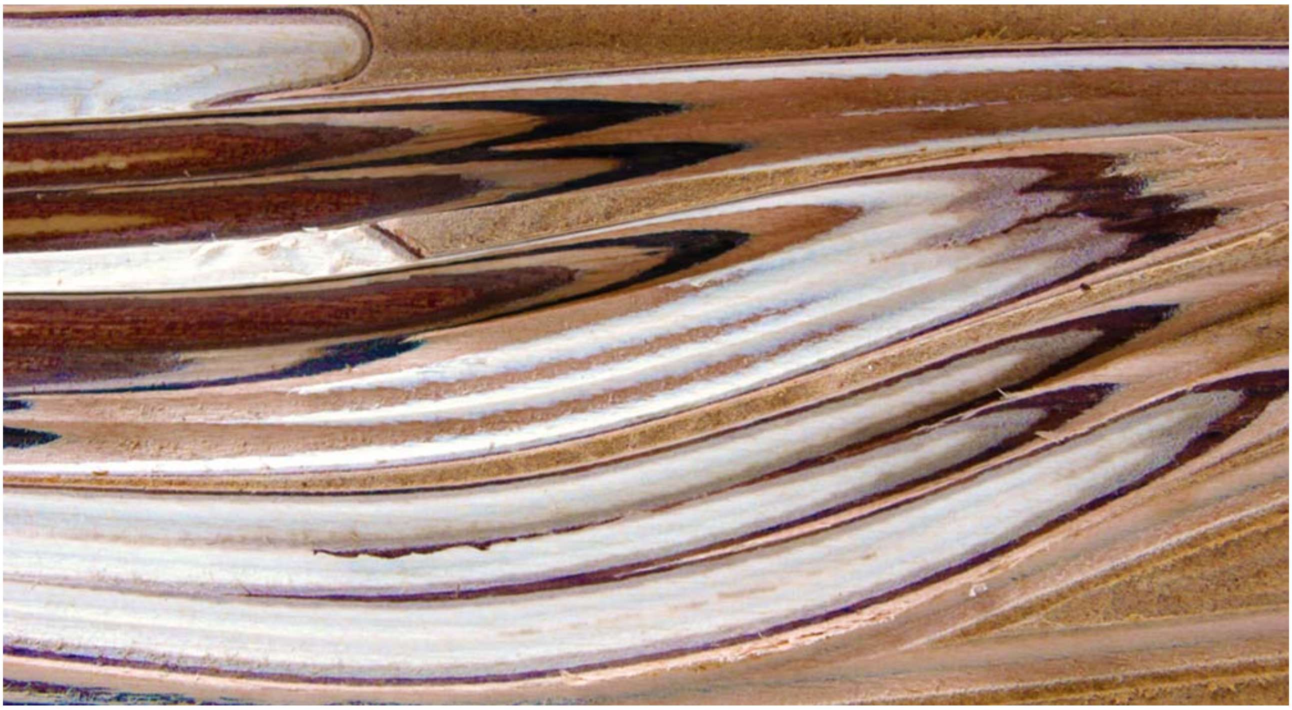
interiorities II: digital field explorations (students: Büyükköz, Kleindienst, Petrovic)



interiorities II: digital model (students: Büyükköz, Kleindienst, Petrovic)

interiorities II: milling results – pattern 1 (students: Büyükköz, Kleindienst, Petrovic)

interiorities II: milling results – pattern 1 (students: Büyükköz, Kleindienst, Petrovic)



interiorities II: milling results – pattern 3 detail (students: Büyükköz, Kleindienst, Petrovic)

All the student projects presented in this paper are selected from design studio work done in Zaha Hadid`s Studio at the Institute of Architecture at the University of Applied Arts in Vienna, Austria. Professor: Zaha M. Hadid. Guest Professors 2008/2009: Patrik Schumacher and Ali Rahim. Scientific Staff: Christian Kronaus, Jens Mehlan, Robert Neumayr, Jan Tabor, Hannes Traupmann and Masha Veech.

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(RRN / END / 20090927)

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