Continuous Oscillations

A didactic for augmenting architectural design education with computational design techniques via integrative feedback loops

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Abstract. *We present and discuss a didactic for augmenting architectural design education with computational design techniques via integrative feedback loops and show examples of student projects. Our goal is to embed new technical skills into existing design abilities as quickly as possible, in order to enable our students to exploit and explore the extended capabilities of digital design techniques within the framework of architectural design projects. We instigate a process of continuous mutual feedback between different fields: on the one hand between technique-based exercises and design-related steps, and on the other hand between the digital and the physical. Through oscillation and feedback, the newly learned skills are directly interwoven with the existing ones. Special emphasis is put on the illuminative effects of transitions between different media and on issues of fabrication.*
Keywords. *Design curriculum; tools; shape studies.*

GENERAL AIM: EXTENDED POSSIBILITIES

Digital tools extend the scope of possible design solutions. With them, designers can formulate, control and construct solutions to design problems that would otherwise be either too time-consuming or impossible to conceive and handle. This is mostly due to the difficulty of the geometry involved (such as intersections between polyhedral or curved elements), or its complexity, its number of elements. It is important for us that our students can understand and handle the new possibilities in such a way that they are free to choose which solution they see as the most appropriate, regardless of matters of complexity, style or form.

DESIGNING WITH NEW TOOLS: THREE TYPES OF OSCILLATIONS

We therefore introduce two things simultaneously: designs tasks that challenge the borders of non-digital possibilities, and together with them digital tools that allow students to cross those borders and extend their own scope of abilities. Thus, the students access new aspects of the design problem from an understanding of new tool possibilities and vice versa. Their learning oscillates between designing and tool acquisition.

Additionally, we always task students with the production of physical models. Building those models becomes possible through the new digi-

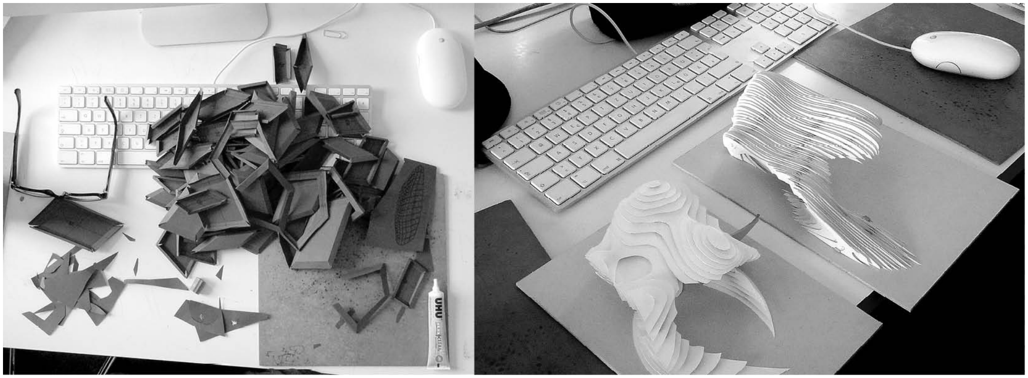


Figure 1
Study models in progress adjacent to Rhino Workstations.

tal design tools. The models are not just for the final presentations, but also sketch models that as early as possible transfer into the physical what was sketched digitally (Figure 1). This has three main reasons: Firstly, physical models in ‚real' 3D space are much more comprehensible and expose a design's qualities much better than digital models projected onto a 2D screen. Secondly, even simple sketch models already start to hint at production challenges that become much more important when building in 1:1. Today, we think, it is rather easy to be seduced by the possibilities of digital tools into conceiving projects that then run into problems when they come to be realized. Early model-making makes the students address such possible difficulties literally at first hand. Thirdly, the transition from digital to physical sometimes comes with mistakes, especially when students try out certain techniques for the first time, experimenting with production tools and materials. Such mistakes can very often be made productive because the ‚wrong' or ‚failed' translations can unintentionally show new aspects of the original that were difficult or even impossible to see there. So a second oscillation occurs between the digital and the physical.

A third oscillation is attempted between the little, simple design tasks in the course and the larger and longer design projects students undertake in parallel courses. The tasks we set are aimed to equip students with techniques that also serve their larger projects, and we invite students to bring problems from their more complex projects into the course so that they can be discussed and solutions be found.

DESIGN COURSE STRUCTURE AND DESIGN TASK SEQUENCE

We have structured our design course in three steps. In each step, a pavilion has to be designed and presented in two-dimensional representations as well as in physical models. Before the precise design task is set, we introduce various CAD tools. The design tasks themselves then include certain requirements, conditions and restrictions which invite if not require employing the tools just introduced.

In each step, the physical models use less material, but the parts are more laborious to assemble.

Where digital models can be made up of geometries that are continuous and as large as designers desire, physical models and - even more so - real buildings have to be assembled from components. The ever faster development of large scale 3D printers only partially remedies this, because the printers mostly rely on very fine strata which, when viewed closely, again dissolve the continuities.

As software we use Rhino in conjunction with its Grasshopper Plug-In. Rhino is in the process of becoming the lingua franca for architectural 3D modeling, dito with Grasshopper for simple programming of such software.

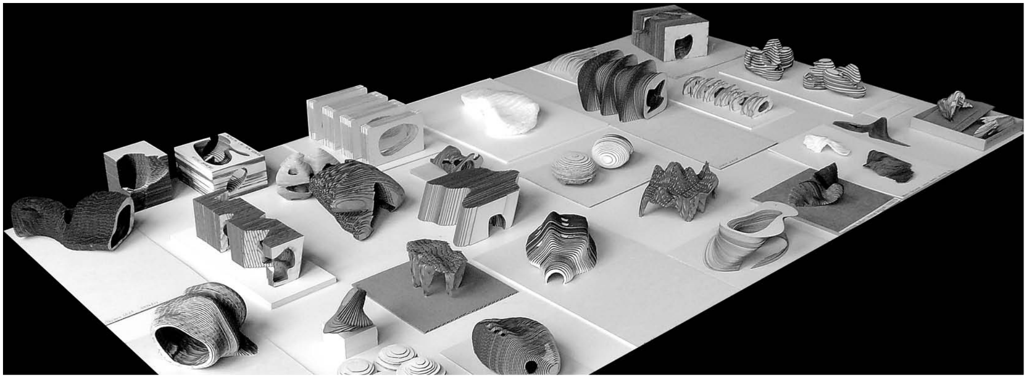


Figure 2
Stratified pavilion models.

MILIEU FOR WORKING AND STUDYING

We chose simple pavilion as topic for the design exercises in order to bridge the gap between exercises dealing with the technical capabilities of the software and the challenges of architectural design - context, construction, spatial program, functionality. Pavilions do incorporate the latter, but to a degree that can be rather freely chosen by the students, so that there remains space for play and experimentation with the former. We strive to create a playground-like milieu where playfulness, experimentation and risk-taking are common, so that students dare to - so to speak - flex the new-found muscles they have been equipped with (meaning the new software tools). We encourage the students to attempts in which they are at first likely to fail. The learning effect, and the sense of self-satisfaction on the students' side, to us appears higher this way. For the students to be able to easily move conceptually we aim to create a ground that is both slippery and padded so that they can move swiftly and fall easily - but soft.

Our intention is that students transfer the new possibilities explored through the new skills acquired onto other design projects they are or will be working on; projects with more numerous and realistic requirements in terms of spatial program, constructability, functionality and relationship to urban and socio-economic contexts. Our more simple pavilion designs are intended to serve as test cases, where investigations can be faster and more radical within a protected experimental realm isolated from various restrictions.

STEP 1: CURVED FREEFORM SURFACES AND STRATIFIED MODELS

The first pavilion has to have various seating possibilities inside as well as outside, and its roof has to be accessible. It has to be a continuous form, not an assembly of components: all functional and circulation elements have to be synthesized and integrated into one coherent shape. Its physical model has to be built from different strata cut manually or with a laser-cutter (Figures 2 and 3).

We introduce free-form modeling tools in two steps: at first solids are manipulated through their control points for quick but imprecise shape exploration. Thereafter, surfaces are created from control curves - a more laborious but much more precise and intentional design method. Sculptural and functional aspects of the created surfaces are discussed, and the relationships between their aesthetical qualities as objects ore public sculptures and their usability as architecture. Categories like 'furniture', 'house', 'wall', 'roof', 'stair', 'ramp' that appeared fixed become fluent. A solution space for architectural design that was compartmentalized becomes a continuum. The prevalence of purely horizontal surfaces in architecture is questioned and uses for inclined planes found and discussed.

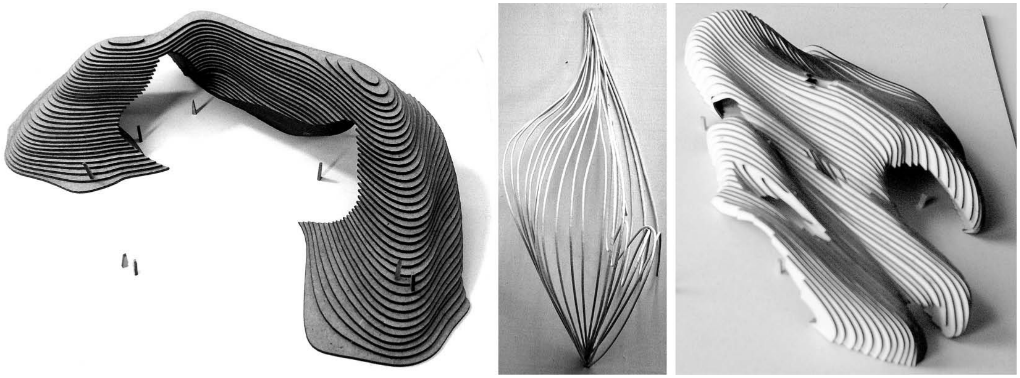


Figure 3
Stratified pavilion models.

The digital designs are then sectioned into strata, stacked vertically or side by side. The stratification becomes a design theme in itself: how are the strata orientated, and how thick are they, i.e. how many of them are there ? Students explore different stratifications, even un-parallel ones, experimenting with radial and curved arrangements and strata that have trapezoid instead of rectangular sections (Figure 4).

Students experience that the stratification can be seen either as an unwelcome tainting of the seductively perfect digital model, or as a means of structuring the endlessly pliable; making it more disciplined and taut.

Very often, the resulting designs play with the difference between outside and inside shape and exhibit rather thick intermediate spaces. Furthermore, students enjoy the possibilities of doubly curved surfaces.

We encourage students to see occasional transition difficulties between digital and physical model-making as 'happy accidents' and exploit those as welcome design ideas (Figure 5).

STEP 2: INTERSECTING SPACES AND DEVELOPABLE SURFACES

The second pavilion has to be the result of three intersecting shapes. The different source shapes have to be recognizable in the resultant exterior shape and create different spatial regions inside. These regions - as opposed to separate rooms - have to be associated with different functions. The hull surface has to be developable and built as a shell as thin as

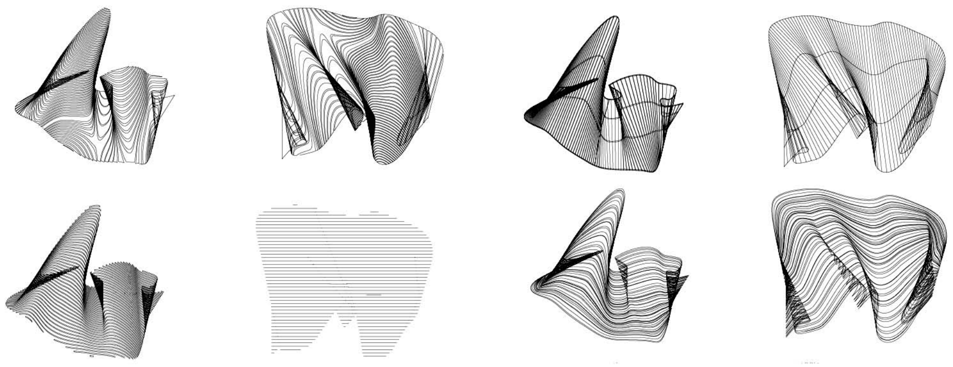
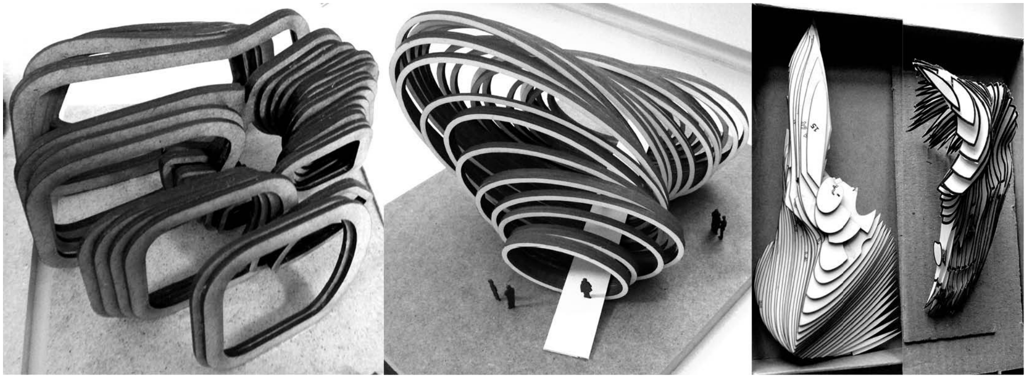


Figure 4
Stratification Studies.

Figure 5
'Happy Accidents': Transition Difficulties between digital and physical exploited as design ideas.



possible. Apart from the technical possibilities of intersecting objects, means of dividing space into different areas other than primitive walls are explored. Boundaries between different regions are discussed as ambiguous. They do not stem from separating elements which are inserted into an already existing shell but result from the mere shape of a complex space. In other words: continuous spaces are differentiated via widening and contraction, embodied in the seams of the different intersections. Furthermore, the possibilities of 'negative' spaces are explored; spaces that are created through boolean difference.

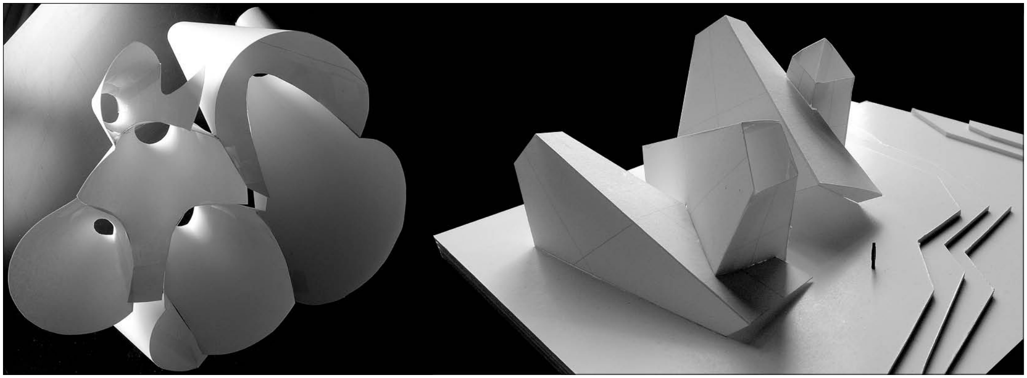
The 'Unroll' command is introduced together with boolean commands for intersecting and splitting shapes and separating and exploring the resulting pieces.

The formal and sculptural freedom experienced in the first task is restricted, but the designs more tightly coupled with the production possibilities. Much less material is used, and its fabrication does not rely on the availability of laser printers (Figures 6, 7 and 8). The interplay between (almost) unrestricted digital form-making and the reduced possibilities of physical production are experienced and discussed.

Special emphasis is put on how additional stability can be achieved in the physical models by having the intersected parts support one another.

Again, we aim to let the students welcome the parameters of physical production into the design as informative factors rather seeing them as obstacles.

Figure 6
Intersecting spaces and developable surfaces pavilion models.



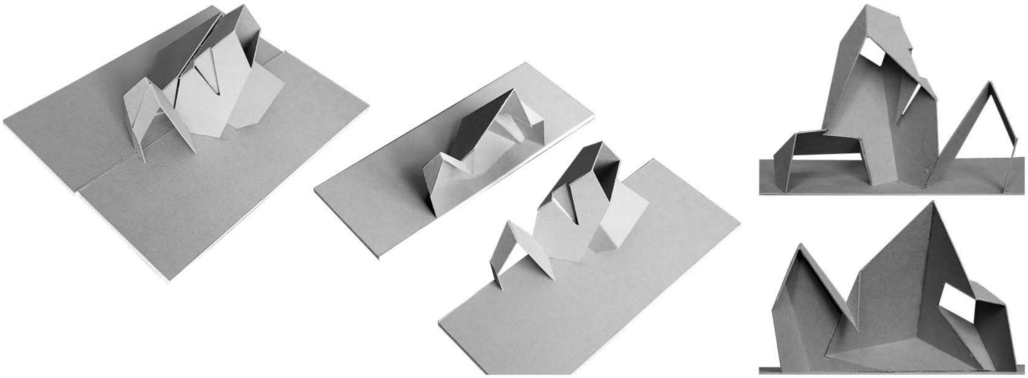


Figure 7
Intersecting spaces pavilion sectional models.

STEP 3: COMPLEX ROOF AND DISSOLVED HULL

The third pavilion is more of a roof, i.e. for an archeological excavation. It has to be a single surface that changes from convex to concave at least once. In order to fabricate it, using Grasshopper the surface is populated with a three-dimensional pattern in such a way that it is divided into multiple developable surfaces. The population pattern has to include holes so that the resulting populated surface becomes porous (Figure 9).

We employ a simple and well-known grasshopper definition that divides a surface into a rectangular grid and maps a given geometry onto the individual cells. The parameters in the definition's most simple form are the surface, the geometry to be mapped, the number of u and v separations and the height of the projections. Occasionally, we extend the definition with more parameters, varying the height or leaving the uniform division of the surface behind more complex patterns.

The de-materialization from Step 1 to Step 2 is further continued as the resulting surface is perforated so that its holes are larger than its solid parts. The geometrical restraints that were introduced from Step 1 to Step 2 are removed again. The formal freedom from in Step 1 is synthesized with the construction capabilities from Step 2.

Students study the effects of the geometry of the population modules and the population system

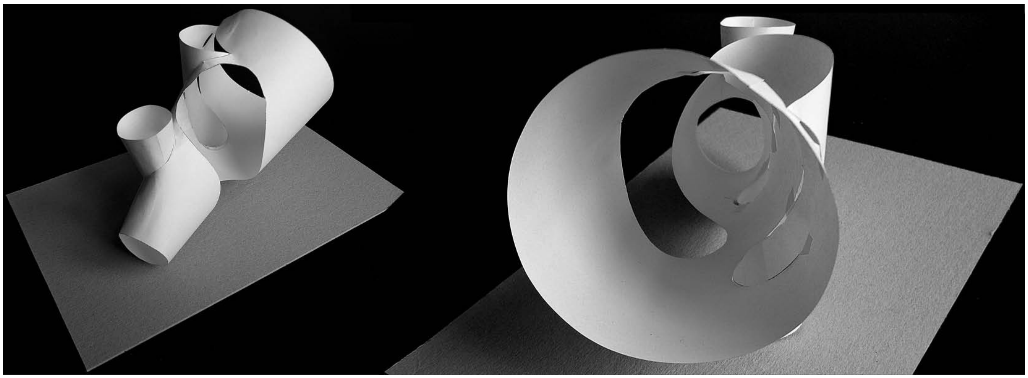
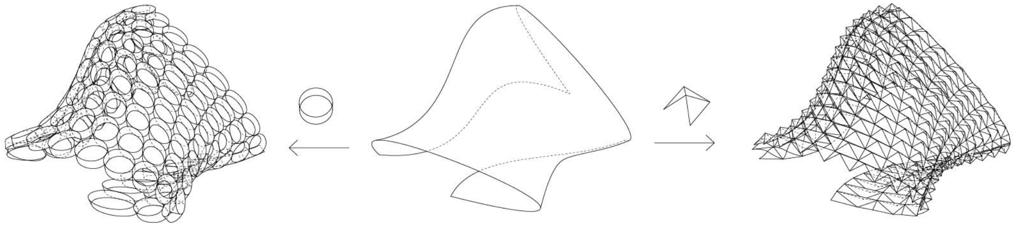


Figure 8
Intersecting spaces and developable surfaces pavilion models.

Figure 9
Three-dimensional pattern population variations.



on the original surface and explore the difficulties and possibilities in fabricating modules and surface (Figures 10 and 11). Certain combinations of surface curvature and mapping height easily create self-intersections. The definition does not check for those - this would have been to difficult to implement within our course structure.

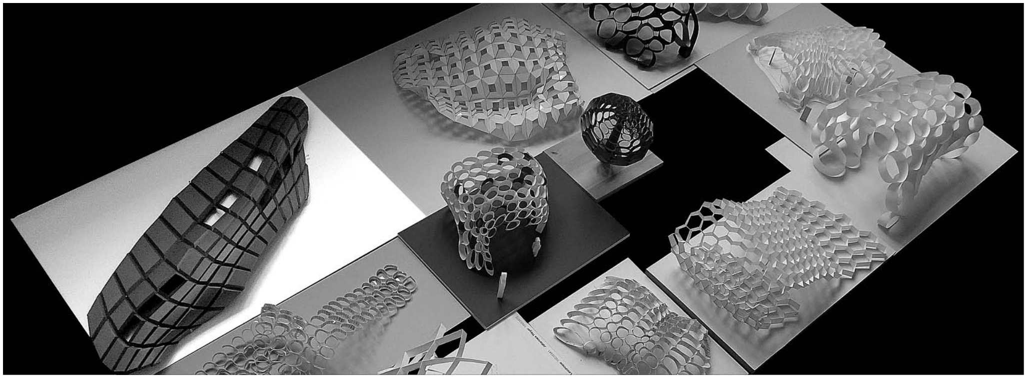
The possibilities of customized mass-production - already hinted at in design step 1 - are explored and discussed.

In order to fabricate and assemble the numerous parts that make up the surfaces, the students, after having worked individually in tasks 1 and 2, now form groups of 3-4. So in addition to the CAD techniques, design possibilities and fabrication methods, teamwork is experimented with: who does what, in which sequence are steps undertaken, how are communal decisions reached ? Such teamwork has always been important in a discipline where, like with composers but unlike visual artists, designers are not builders. It is, though, becoming ever more important as the growing number of design tools and fabrication methods increases the number of specialists while decreasing the percentage share of existing skills that any individual can have - thereby raising the number of specialists and therefore the need for shared work and communication of goals, intentions and ideas.

CONCLUSION AND OUTLOOK

In order to extend existing design skills, we introduce technical possibilities of CAD software with conceptual and geometrical design tasks. We attempt 3 oscillations: between technical tools and design possibilities, between digital and physical models, and between simple architectural designs within the design course and the larger design projects students work on in parallel. These repeated movements between different modes of working in time weave numerous conceptual strands that be-

Figure 10
Complex roof and dissolved hull pavilion models.



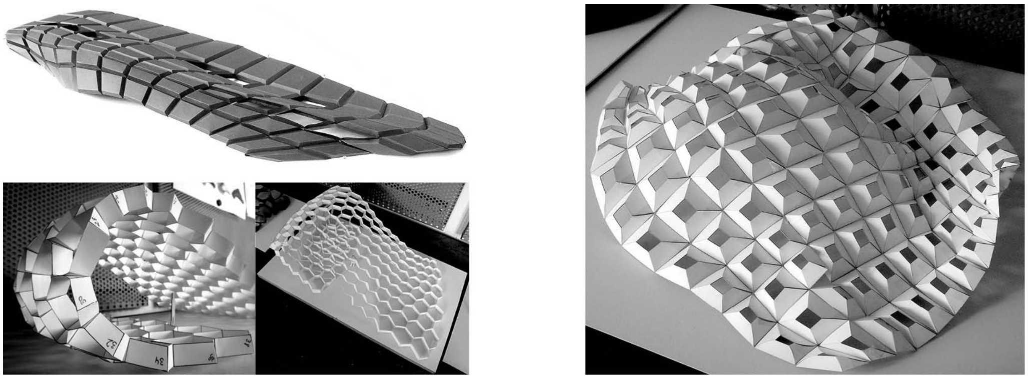


Figure 11
Complex roof and dissolved hull pavilion models.

gin to tie different conceptual regions into a whole.

In the future, we aim to intensify this weaving, especially of the work done within the design course and the work done outside of it, so that the new territories opened up for designing architecture can be traversed more naturally.