

Differentiated Continuity and Mutual Support

How Intersecting and Unrolling Operations, Made Manageable through CAD, Facilitate Richer and More Effective Spatial Articulations

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The two geometric operations of intersecting shapes with one another and unfolding complex shapes into flat patterns have through CAD software been changed from challenge to triviality. Thus, combinations of shapes that have eluded designers for the difficulty of their handling are now at the hands of everybody who is able to use common CAD packages. We investigate what this can mean for architectural design.

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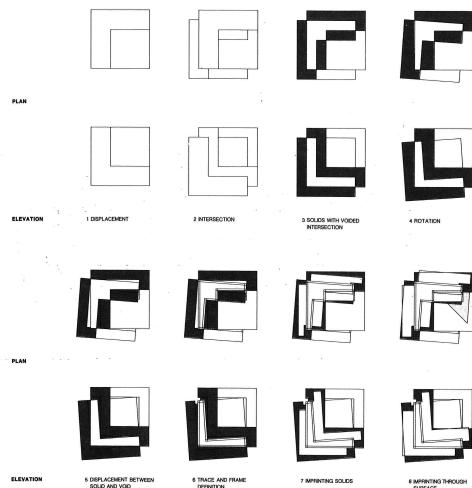
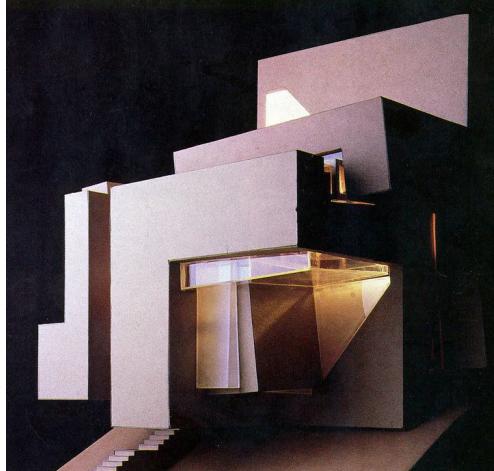
Figure 1
Groin Vault: Palazzo
della Ragione

A BRIEF HISTORY OF INTERSECTING SHAPES IN ARCHITECTURE

The employment of intersecting shapes in architecture has largely been confined to cuboids and cylinders, the latter already testing the limits of geometric and physical constructability. Since their conception in greek and roman architecture, groin vaults made from the intersection of two equal cylinder halves, have been the epitome of complexity in this regard (Figure 1).

Only the advent of CAD software that aided the precise determination of three-dimensional intersections changed this in the 1980s. Architects like Peter Eisenman began to develop architectural designs employing numerous, sometimes excessively many intersections and overlaps - perhaps demonstrated in its most extreme form (Davidson 2006) in Eisenman's never-built design for the Guardiola House in 1988 (Figures 2, 3).





Where traditionally, the different sculptural and spatial segments or parts of a building were situated adjacent to one another, merely touching each other, here, in Eisenman's sculptural articulation, they merged, two elements creating an intersection as a third element - something that was shared by both and yet singular, its own self yet dependent upon its neighbours. Whether Eisenman's employ-

ment of these overlaps enriched the users' possibilities or remains a somewhat elaborate yet new form of sculptural ornament remains difficult to judge. It certainly expanded the designer's sculptural toolset and allowed him to conceive of hitherto unseen sculptural configurations. Eisenman does not intersect different forms but repeats one rectangular basic module, offsetting it in space while rotating it slightly. This subtle modification ensures that the resulting overlaps become complex but not chaotic and that the design retains a degree of discipline and sculptural soundness. Unlike the Vitra Museum, designed and built by Frank Gehry at about the same time (in 1989; Gehry 1993 and Kries/Thieme 2013). While this design is also conceived by overlapping several distinct shapes, here the shapes are very different from one another (Figure 4). The sculptural result is much more complicated. And the actual intersections are more or less ignored by Gehry. The interest here appears to be primarily with creating a kind of spatial collage; various shapes stuck together, only creating one singular space because they overlap one another.

Figure 2
Peter Eisenman
Guardiola House
physical model



Figure 3
Peter Eisenman
Guardiola House
intersection studies

Figure 4
Frank Gehry
Vitra
Design Museum

Both Eisenman's and Gehry's projects deal more with novel outer appearances than with internal spatial possibilities. Those are investigated in projects by the practice of Herzog de Meuron who systematically experiment with intersecting shapes and constructing buildings of various complexity and usability on the basis of these experiments. One example of this is the Jinhua Reading Space from 2007 (Figure 5): De-

Figure 5
Herzog de Meuron
Jinhua Reading
Space

veloped from two extrusions of an irregular surface tiling intersecting one another at an angle of 90 degrees, the building is of no clear function, yet inviting playful exploration by its users and dissolving the boundaries between wall, ceiling, furniture and circulation element.



A second example is the Vitra House from 2011 (Figure 06; Márquez Cecilia and Levene 2010, Kries and Thieme 2013).

Figure 6
Herzog de Meuron
Vitra House



Figure 7
Zaha Hadid
Zaragoza Bridge
Pavillon



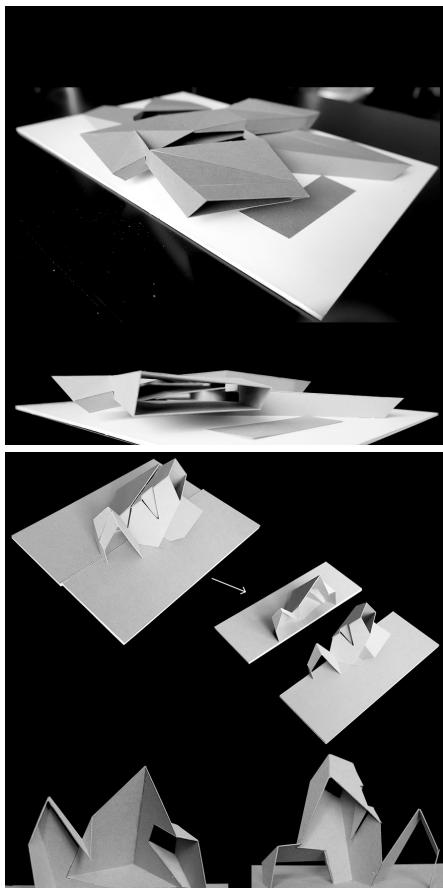
One simple and generic cross-section is extruded, and the resulting duct-like shape used as a module that is stacked in space in such a way that neighbouring modules intersect one another. While borrowing its degree of sculptural complexity combined with discipline and soundness from Eisenman's Guardiola House, it is nevertheless much more interested in the inside where the intersections literally open up surprising vistas and spatial relationships. Where in Gehry's Vitra Museum the intersections are ignored, here they mark the positions of circulation and galleries. One more example is Zaha Hadid's Zaragoza Bridge Pavillon (Figure 7) where yet another possible use of the intersections is investigated: Combining several tube-like bridge structures in such a ways that an internal spatial complexity is achieved while the structural soundness is retained (Jodidio 2013).

All five projects would have been very difficult to develop had it not been for the availability of software that actually calculated the intersections.

2. UNROLLING SURFACES

Similarly to intersecting surfaces, unrolling them is incomparably simpler with CAD software than without it. Plane cutting patterns allowing simple manufacture of surfaces can easily be produced. Again, this extends the scope of designers' possibilities much beyond what was attainable without the aid of CAD software. Unrolling surfaces and constructing complex curvatures, something that was largely ignored in architecture, had to be developed into an art form in ship-making has now become something of a commodity. Complex unrolled surfaces become something like cutting-patterns for clothing, moving the discipline of architecture closer to that of tailoring or cloth-making, echoing Gottfried Semper's likening architecture to people's 'third skin' (Semper 1860), with the natural skin people's first, and clothing people's second skin. Though while Semper keeps within his metaphor the fact that a skin is draped over something (natural skin as well as clothing) and a building's skin therefore draped over a structure, a surface curved or folded in an appropriate manner can

itself act structurally, keeping itself upright and even supporting other elements. Therefore the employment of unrolled curved or folded surfaces opens up the possibility of freeing the understanding of architecture as a third skin from the implications of decoration that Semper's reliance on a substructure necessitated. If one regards coherence of overall structure and mutual dependability of elements as qualitative aspects of architecture, the union of skin and structure made easier or even possible through developable surfaces surely is not unwelcome.



3. STUDENT DESIGN EXPERIMENTS

These observations above form a basis for us to conduct studies concentrating on the possible sculptural and spatial qualities intersecting surfaces can offer architectural design. Developable surfaces of increasing complexity and number are intersected, and we study the resulting spaces in terms of geometry, buildability, spatial and conceptual qualities (Figures 8-11).

Of special interest to us are several conceptual factors: on the one hand the ambiguity of spatial regions within a shape that is the result of an intersection. When two shapes intersecting create three regions - to which shape does the new, third one, belong? How is it connected to its neighbouring regions, being distinct yet part of a whole? On the other hand, how are the new, emerging regions articulated, or: which part(s) of the intersection operation are actually used, which ones discarded? Mostly, spaces in architecture are clearly subdivided into parts. Intersections allow designers to soften transitions between regions, that is to say blur the boundaries between them. Even with just three or four shapes intersecting, the results become very complex quickly. How can designers keep a balance between differentiated articulation and comprehensibility? We do not seek theoretical answers to these questions, but address them in the projects themselves by attempting to articulate various answers. We find that the new geometric possibilities open up new conceptual ones. In terms of buildability, we develop physical from digital CAD models. Thus, we can also test the stability of the intersection results. Especially when curved parts are used, interesting possibilities emerge for constructions that use parts which are leaning against one another to achieve stability. In digital space non-developable surfaces can be applied with the same ease as developable ones. When it comes to physical production, though, this difference becomes important. Developable surfaces are much easier to produce, most importantly for us they can be built from folding patterns that the 3D modelling software can produce. We strive to not see this

Figure 8
Student Project
Andreas Beck, Erfurt
School of
Architecture

Figure 9
Student Project
Konrad Höfer, Erfurt
School of
Architecture

as a limitation but as a conceptual tool to make the designs more stringent. All studies are conducted as part of an ongoing project with students of architecture that combines learning new geometrical skills with historical review and experimentation in terms of constructability and architectural conceptualization.

Figure 10
Student Project Lisa
Dorno, Erfurt
School of
Architecture

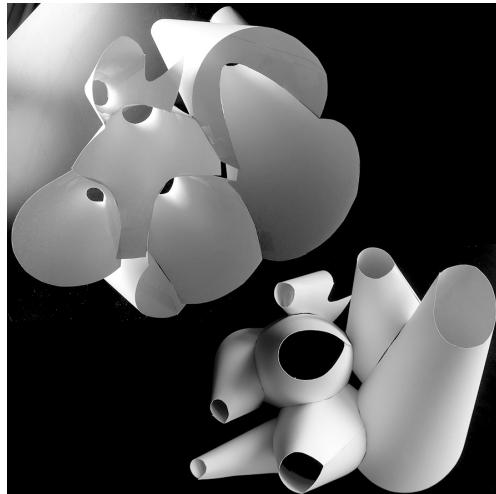
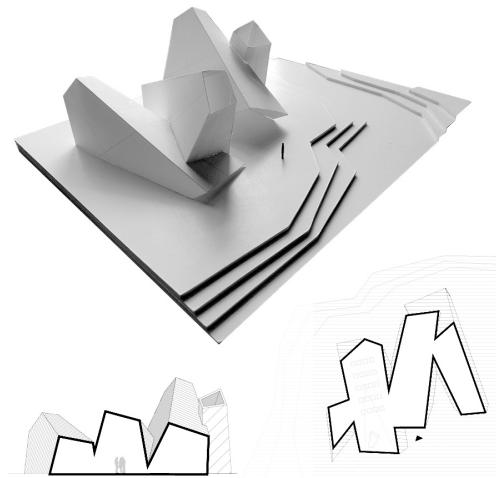


Figure 11
Student Project
Madeleine Nolle,
Erfurt School of
Architecture



CONCLUSIONS AND OUTLOOK

Overall, we observe that architectural designers' spatial and sculptural repertoire - and with it their conceptual field - can be expanded through the increased possibilities CAD offers for intersecting shapes, and unrolling the results for production purposes. We will continue, expand and systematize our investigations with a focus on functional and structural aspects. More specifically, will study the results of intersections of increasingly complex and exotic shapes (how does the complexity and level of exotism of the source shapes relate to those of the resulting intersections ?), the results of different numbers of intersecting shapes (how does the complexity of the intersections relate to the number of source shapes), and the relationships between the stability (or non-stability) of the source shapes to those of the resulting intersections.

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