Versioning: Architecture as series?

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Abstract

This paper investigates the role of versioning in contemporary theory and the practice of design. The introduction of computation done by computers allowed for complex mathematical calculations and their visualization, which were for long time simply too complex. Today, differential calculus – underlying most interactive 3D modeling software – has significantly informed the production and conceptualization of architecture. The upshot of this transformation is that we are now witnessing a shift from an architecture of modularity towards an architecture of seriality, design versions. The core idea of versioning exceeds simple variation between different parameterized design iterations, versioning rather also operates at the micro-scale, within the structure and aesthetic of digital design itself.

1. From Modularity to Seriality

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The introduction of computation done by computers allowed for complex mathematical calculations and their visualization, which were for long time simply too complex. Today, differential calculus – underlying most interactive 3D modeling software – has significantly informed the production and conceptualization of architecture. The upshot of this transformation is that we are now witnessing a shift from an architecture of modularity towards an architecture of seriality. To understand this shift we will first focus on the idea of modularity.

In 1926 Walter Gropius suggested:

“The systematic preparation for a rational housing construction will serve the development of dwelling. [...] The creation of types [...] is an effective tool to create better and cheaper with industrial production a new manifold of products. Therefore it is logical to serve the masses’ everyday need through standardization. Each individual has the choice between the side-by-side developing types. The building and their furnishing will vary in their totality corresponding to the number and difference of the inhabitants, while their constitutive elements will remain the same.”

Grundsätze Bauhaus Dessau, W. Gropius 1926.
In 1926 the Bauhaus postulated that new industrial production techniques would significantly change the modes of designing and producing architecture – and ultimately the modes of dwelling. The creation of prototypes and the introduction of modularity seemed then the key to success. While the modernist architecture was based on a classical mechanistic paradigm, which envisioned a machine for dwelling assembled out of a kit of parts, today’s architecture is increasingly informed through the trans-classical Turing machine – the digital computer.

In 1936, the model for the Turing Machine [Fig. 1], developed by English mathematician Alan Turing, laid the theoretical foundation for computing. In principle, the machine could be physically assembled out of a few components: a table of contents that held the rules for its operations, a reading and writing head that operated according to those rules, writing 0s or 1s – the code – on an infinitely long tape. The moving head followed three modes of operation: writing, scanning, erasing.

Figure 1: Alan Turing, Turing Machine, 1936


Though basic, Turing considered his machine universal in the sense that it could simulate all other (calculable) machines. It had the unprecedented ability to emulate divergent and multivalent processes, and it could even initiate recursive processes – processes that would repeat themselves in a self-similar way.

Turing did not envision his machine as a practical computing technology, but rather as a thought experiment that could provide – independent of the formalism of traditional mathematics – a precise definition of a mechanical procedure – an algorithm. A computer program is essentially an algorithm that determines and organizes the computer’s sequence of operations. For any computational process, the algorithm must be rigorously defined through a series of finite well-defined steps that determine the order of computation.
Obviously, the formalization of the design process in order to capture it algorithmically at first introduced a level of control into architecture, which countered the influence of intuition. Algorithmic design, design with the computer, seemed more about creating mechanisms and codes for control than about design. The hype of the digital medium along with the fascination for cybernetics and information theory throughout the 1950s and 1960s was therefore quickly followed by disenchantment. The ‘algorithmization’ of design processes seemed to most architects overly constraining and stifling of creativity. And it was only with the proliferation of personal computers and mostly calculus-based interactive software that computer-based architectural production and construction proliferated and eventually began to challenge the profession’s inherited logics of operation. This was in the 1990s, more than 50 years after the invention of Turing’s machine and 70 years after Gropius’ request for a prototypical industrially mass-produced building components that would assemble unique buildings.

With the introduction of digital media, the conception of modularized architecture constructed out of nearly identical industrially mass-produced components, and thus Gropius’ thesis, has been challenged. Today, with the use of the computer and calculus-based software, architecture can instead be conceptualized as a series.

A series is a framework of parameters designed by the architect, within which a variety of design versions may be realized. Each of these design versions is unique and yet also part of the series. The parts assembling each of the series’ designs are no longer necessarily mass-produced but could rather be mass-customized.

The argument is not new but is frequently overlooked. Already Greg Lynn wrote in his introduction to the 2nd edition of Folding in Architecture (2004) about the centrality of the digital medium and the role of the differential calculus for rethinking architecture as a series. Retracing Lynn’s debate on the role of calculus back to 1993 when the first edition of Folding in Architecture was published, this paper wants to shift attention from the highly formal-driven use of the digital medium associated with ‘literal folding’ or ‘elegance’ to arrive at a critical assessment of differential calculus and its potential to challenge traditional modes of designing, producing, and constructing architecture.

2. Differential calculus: Folding elegant architectures?

Gilles Deleuze’s book “The fold: Leibniz and the baroque,” first published in France in 1988, began to spread its influence throughout the US American architecture scene in 1993 when it was first translated into English and quoted in the Architectural Design Magazine “Folding in Architecture.” Greg Lynn, the guest editor of this magazine, intended to rethink architecture countering both the Deconstructivists’ discontinuity and Venturi and Scott Brown’s heterogeneity. Lynn advocated instead the continuous, the continuously differentiated, for which Deleuze provided the philosophical argument and perhaps more importantly the figure of ‘the fold,’ which was to preoccupy architects for the next decade – resulting in folding cities, folding grounds, folding buildings, folding interiors, folding done by anybody, anywhere, at any time.

What was the fascination that emanated from Deleuze’s reading of Leibniz?
For Lynn, a young architect working with the latest software based on differential calculus, Deleuze’s reading of Leibniz gave birth to a new logic, that of the “integration of differences within a continuous yet heterogeneous system.” It was 1686 when Leibniz, a well-known German politician and philosopher, propagated his idea of differentiation with “*Nova Methodus pro Maximis et Minimis, Itemque Tangentibus, qua nec Fractas nec Irrationales Quantitates Moratur, et Singulare pro illi Calculi Genus.*” Leibniz invented with differentiation a method that could calculate and thus comprehend the rates of change of curves and figures. Differential calculus was soon applied for the graphing of physical phenomena of movement or the graphing of curves for the construction of ship and bridge designs. (7)

Besides its practical application, Leibniz’s differential calculus also had philosophical implications, as it could analyze and thus allow the comprehension of nature as a ‘continuous variation,’ as a ‘continuous development of form.’ In Deleuze’s reading of Leibniz, differences were hereby no longer thought of in terms of separate entities, but rather in terms of a continuous differentiation according to contingencies; a process Deleuze termed *folding.*

*Folding* in Architecture stands according to Lynn for a flexible organization in which dynamic relations replace fixed coordinates as the logics of curvilinearity [Fig. 2] depicted by Leibniz’s differential calculus underlie the system. Perhaps most notably, with software based on differential calculus architectural forms changed “from fragmented polygonal rectilinearity towards smooth continuous splinal curve-linearity, [...] subverting both the modernist box and its deconstructionist remains.”

**Figure 2:** Greg Lynn, Differential Curvature, 1999.

Besides Lynn, one other advocate of *Folding in Architecture* was Lynn’s teacher and employer Peter Eisenman. At first glance, however, Eisenman’s triangulated Form Z-generated architectures [Fig. 3] of the early 1990s had – at least superficially – next to nothing to do with either *folding*, curvilinearity, or Leibniz’s differential calculus.
And yet its author Eisenman insisted at length on the dramatic implication of Leibniz’s mathematics for architecture, explaining folding in topological terms:

“A folded surface maps relationships without recourse to size or distance; it is conceptualized in the difference between a topological and a Euclidean surface. A topological surface is a condition of mapping without the necessary definition of distance. And without the definition of distance there is another kind of time, one of a nomadic relationship of points. These points are no longer fixed by X, Y, Z co-ordinates; they may be called x, y, and z but they no longer have a fixed spatial place. In this sense they are without place, they are placeless on the topological ground. [...] Here the topological event, the dissolution of figure and ground into a continuum, resides physically in the fold; no longer in the point or the grid.”

Folding is seen by Eisenman as a possibility of changing the conception of space, as it draws attention to that which is commonly overlooked: the coordination of space and architecture.

Eisenman refers particularly to the most dominant of the coordination devices used in architecture: the so-called Cartesian Grid, the ubiquitous Cartesian coordinate system, that initially was developed to allow for the algebratization of geometric forms, combining mathematical calculation and visualization – two otherwise entirely distinct methods – in one machine. The mathematician Gaspard Monge elaborated in 1799 a descriptive geometry at the École Politechnique that radicalized elementary geometry. [Fig. 4] Monge’s invention was a three-dimensional spatial construct that would allow him to map complex geometries and their distribution and relation in space through orthographic projections onto reference planes. The mathematicians Monge, Poncelet (continuity principle), and Brianchon (principle of dualism) utilized the Cartesian coordinates for the mapping and generation of complex curves and surfaces. The so-called Cartesian grid served hereby merely as an abstract machine that would ease the placement of points in space.
Today Monge’s invention serves as a tool to reinforce and consolidate standardization and stasis – an idea that Monge’s Colleague and Architect J. N. L. Durand initiated, whose interpretation of Monge’s grid widely differed from the abstract machine the mathematician had imagined as a tool for mapping movement, dynamic relationships, and curvilinear complexities. In Durand’s hands Monge’s imaginary grid turned into an universal planning grid, according to which walls and columns were positioned and extruded in a net-like layout. Instead of utilizing the coordinate system as an abstract numerical mapping device, Durand produced gridded architecture by literally building out the coordinate system’s units. With Durand’s interpretation the Cartesian abstract grid transformed – turned from an abstract machine – into architectural determinism that unfolded along the grid of predetermined lines, and that would become represented along the grid’s orthogonal projection planes.

Contemporary architectural drawing conventions still prefer representations which were long ago established through Durand’s institutionalized depictions – that is, the section, elevation, and floor plan. Durand’s determinism eagerly coordinated – even typified – with the aid of the Cartesian grid the real, thereby greatly ignoring the abstract machine’s potential for speculation and for analysis of the a priori indeterminable.

Today, with every usage of standard architectural software – given that it is based on the Cartesian grid – inherited standards, norms and associations become automatically re-installed. Every digital, discrete image is characterized through uniform subdivisions, a finite Cartesian grid of cells – the so-called pixels. Facing the ubiquitous inscriptions of griddedness, it seems all the more necessary to remember that all standards are arbitrary mental constructs. Any standardization is arbitrary, as any tool and software preference is arbitrary – and hence potentially open for change.

Eisenman advocates this change, suggesting that the fold could replace the Cartesian grid and hence the comprehension and production of space associated with it.
3.0 Folding versus gridding

Folding, the process of differentiation based on Leibniz’s differential calculus, turns in Eisenman’s hands into the fold, a formal tectonic, thought to be capable of changing not only traditional viewing conventions, but also inherited conceptions of space. [Fig. 5] The fold seems – at least to Eisenman – a perfect device with which to play his games of confusing the imaginary with the real, and the real with the imaginary. The fold presents an alternative to the grid of Cartesian descent as it presents a challenge – if not a catastrophe – for architecture’s planometric means of representation, which simply cannot cope with the spatial complexities characteristic of the fold. With the new means of presentation, new realms of architectural thought and production become possible, as the designer is liberated from the constraints of traditional models of presentation.

Figure 5: Peter Eisenman: Emory University Center of the Arts, Atlanta 1991 – 1993, Folding auditorium, Form*Z, Chipboard Model.

Eisenman writes that the moment in which “space does not allow itself to be accessed through gridded planes”¹¹ is the moment in which the architect realizes that the process of imaging was always already present in the process of design and its realization – and thus inscribed itself into the material substance of architecture.

Had Architecture in the past been literally informed through the so-called Cartesian Grid, so it is in the present, as Eisenman further speculates, informed through the ‘fold,’ alias differential calculus:

“Leibniz turned his back on Cartesian rationalism, on the notion of effective space and argued that in the labyrinth of the continuous the smallest element is not the point but the fold’. If this idea is taken into architecture it produces the following argument. Traditionally, architecture is conceptualized as Cartesian space, as a series of point grids. [...] In mathematical studies of variation, the notion of object is changed. This new object is for Deleuze no longer concerned with the framing of space, but rather a temporal modulation that implies a continual variation of matter. The continual variation is characterized
Eisenman depicts here what I first termed versioning\textsuperscript{13} in 2003 - thinking of design no longer as a single entity characterized by an essential form but rather as a series. Each design-event is hereby comprehended as a unique intricate version of a whole series of possible designs - all characterized through continuous similarities rather than clearly defined differences. In this sense, folding could have been interpreted by Eisenman as the divergence from the Modernists’ mechanical component-based design and construction technique.

Eisenman’s own architectural solutions, nevertheless, remained literal folds, which never realized the potential of his own readings, never inquired into the role of differential calculus for the physical realization of his architecture. Nevertheless, Eisenman challenged, regardless of the literalness of his folding architectures and cities, the perception and comprehension of space. Eisenman’s architectures destabilize, displace, and make all those accustomed to orthogonal Cartesian Space simply sick.

4.0 Parametric Design: Architecture as series

While in 1993 the architects included in the seminal AD article were merely compelled by the potential of the concept of folding, it was not until recently that a more critical – and yet still perfunctory - assessment of the concept, and its underlying logic of differential calculus, has occurred. Greg Lynn thinks thus today of his design as a series, as versions. Consequently the most interesting to him, is less the literal production of folded architecture, but Leibniz’s differential calculus and its ability to fuse the hierarchy of parts and whole to produce a deeply modulated whole as well as infinitesimal variation among parts.

The Embryological House (1999) is a highly diagrammatic version of an architectural series, but it is also one of the few examples in architecture up to today which explicitly conceptualizes the idea of differential calculus. Lynn’s Embryological House [Fig. 6] is a series of one-of-a-kind houses that are customized for individual clients.
The houses claim to be adaptable to a full range of sites and climates. Lynn describes the *Embryological House* as a strategy for the invention of domestic space that engages contemporary issues of variation, customization and continuity, flexible manufacturing and assembly. Overall an ambitious concept which never left the stage of a sketchy proposal.

A system of geometrical limits liberates an exfoliation of endless variations:

"I design not just one or two of the *Embryological House* instances. [...] It is shocking how few architects can get this because they are so used to thinking of design as a once-and-for-all problem and not serially. Most architects want to understand the *Embryological House* experiment as a search for an ideal house – as if the whole collection of houses [...] was a conceit to then select the best one. They are all equivalent. I love them all equally as if they were my children [...]. The design problem was not the house, but the series, the entire infinitesimally extensive and intensive group."¹⁴

At the prototyping stage of the *Embryological House*, Lynn developed six instances exhibiting a unique range of domestic, spatial, functional, aesthetic and lifestyle constraints. In the project description he emphasizes that:

"There is no ideal or original *Embryological House*, as every instance is perfect in its mutation. The formal perfection does not lie in the unspecified, banal and generic primitive, but in a combination of the unique, intricate variations of each instance and the continuous similarity of its relatives. The variations in specific house designs are sponsored by the subsistence of a generic envelope of potential shape, alignment, adjacency and size between a fixed collection of elements. This marks a shift from a Modernist mechanical kit-of-parts design and construction technique to a more vital, evolving, biological model of embryological design and construction."¹⁵
Lynn proposes that identity, signature, and meaning tend to move today through series rather than single objects. Calculus is the mathematics for defining these kinds of ensembles. The Coffee & Tea Towers [Fig. 7] Lynn designed for Alessi are testing this premise as an ensemble of mass-produced one-of-a-kind objects. The set is designed so that there are three modules of container: large and medium sized pots for hot water, coffee, tea and milk, and small containers for cream, sugar and lemon juice. These containers share the same form at their edges so that they can be combined in various radial arrangements. The pots are designed by combining nine differently shaped curves. The vessels are formed of thin metal titanium sheets using heat and pressure.

![Image of Coffee & Tea Towers](image-url)

*Figure 7: Greg Lynn: Alessi Coffee & Tea Towers, 2000-2003.*

Up until now, it is product designers and car designers who have grasped the concept much more easily, that the design problems of a series, rather than of a single design, are the issue today. Perhaps it is for this reason that Lynn has tested his concepts with product designs for Alessi, rather than with architecture for a client.

5.0 Versioning: Cross scalar seriality
The core idea of versioning, however, goes far deeper than simple variation between different parameterized design iterations. Both the power and the limitations of versioning-as-series is demonstrated by Lynn’s work – which both suggests the possibility for limitless parameterization across a series. Versioning, however, also operates at the micro-scale, within the structure of digital design itself.

The key to a deeper understanding of the thorough infiltration of the versioning idea into contemporary aesthetics is the long delay between Leibniz’s discovery of calculus, and its common usage in design. The sinuous curve and biomimetic form itself isn't difficult to accomplish without computers. What is rather difficult is to make it mathematically malleable and variable. This is where a higher-order thinking comes in -- it is not just curves themselves, but curves of curves, recursive functions as they literally inform computer-generated form.

The computer's power is in its tireless looping -- its ability to perform millions of operations in a single second, and to constantly shift and recalculate functions continuously. It is not just “the curve” which characterizes digital form, but the parameterized curve – the folding and shifting of the two-dimensional curve across a third dimension. [Fig. 8] Not the curve alone, but also its derivatives and inflection points – the core of calculus-based mathematical analysis – is that which informs digital form-making at its deepest level.

Figure 8: Rocker-Lange Architects, cross scalar seriality, 2008.
Versioning is at the core of the digital form itself; its signature and its authenticity derive from the parameterized repetition which give computer-generated design its characteristic combination of tightly disciplined structure and formal variability. It’s not just the new calculus-powered curvaceousness, which is characteristic of a digitally informed age; it is also a disciplined groundwork of order that underpins the whole operation -- the rhythm of a powerful Turing Machine that drives the versioning at the heart of the digital aesthetic.

Is designing architecture then nothing other than curve analysis?

Not at all; on the one hand, the aim of versioning is certainly not to excel in the use of differential calculus, nor to turn architecture into curve sketching – it is rather a case sensitive tool for the critical assessment of highly specialized needs, that could range from environmental factors to personal preferences. And furthermore, versioning is not just the key to a hyper-individuality of design, but is rather a crucial component of digital production.

*Figure 9: Rocker-Lange Architects, Explorations in cross scalar seriality, 2008.*

For the last two years, my research in algorithmic architecture at the Harvard Graduate School of Design\(^1^6\) has focused on versioning understood as *cross scalar and cross functional seriality*.

One focus of the study is the role of differential calculus for the generation of surface, in which “surface” may hereby be considered at once structural and ornamental, functioning and signing.
The intent is to design and control the surface, highlighting infinitesimally scaled components. By embedding the idea of versioning into the scale of the design itself — that is, into the gradients, which repeat and dissolve across a surface, a loss of modularity in favor of the infinitesimal component occurs. Architecture is viewed neither as fragmented nor contradictory, but rather as an integrative intensive whole.

With computer-controlled manufacturing techniques, infinitesimal variations and "one-of-a kind customized variety" is now possible. This is why code matters.

Endnotes

2 The word 'algorithm' etymologically derives from the name of the 9th-century Persian mathematician Abu Abdullah Muhammad bin Musa al-Khwarizmi. The word ‘algorism’ originally referred only to the rules of performing arithmetic using Hindu-Arabic numerals, but evolved via the European-Latin translation of al-Khwarizmi’s name into ‘algorithm’ by the 18th century. The word came to include all definite procedures for solving problems or performing tasks.
Originally published in French:
6 Gottfried, Wilhelm Leibniz "A New Method for Maxima and Minima, as Well as Tangents, Which Is Impeded Neither by Fractional nor by Irrational Quantities, and a Remarkable Type of Calculus for This,” 1684.
7 The other great discovery of Newton and Leibniz – closely related to the finding of the differential calculus – was the finding of areas under curves—the integral calculus. Leibniz approached this problem by thinking about the area under a curve as a summation (b) of the areas of infinitely many infinitesimally thin rectangles (dx) between the x-axis and the curve.
"Der Raum läßt sich nicht weiter durch gerasterte Ebenen erschließen.”
15 Greg Lynn, FORM, project description for the Embryological House.
16 The research took place in cooperation with Miranda Callahan, co-author of this text’s section "Versioning: Cross scalar seriality” and Christian J. Lange, Rocker-Lange Architects.