The Structure of Vagueness

Analog Computing

Within the history of methodologies in architectural design, the usage of empirical techniques has been somewhat obscured and hidden. Design methods tend to be based on historical references, canonical buildings, laws of proportion, symbolic language, or simple experience and tradition. Though it is common knowledge that architects make scale models, often in wood or plaster, we must keep in mind that these models are mere representations and as such don't inform the built result. I would like to look here at special cases in which the models' materiality itself generates form and structure. It is not very well known that engineers have used material models to actually generate forms and structures rather than to imitate them on a smaller scale. From the 18th century to the 19th, engineers in England and Germany used so-called catenary techniques to test designs by architects; for instance, Robert Hooke used suspended chains to see if arches designed by Christopher Wren actually fit within the desired curvature. Of course, the catenary curve hangs downward, which means the chain's links are all in tension, while in an arch all bricks are in compression. Such an inversion is a discovery of considerable magnitude. What remains unclear, however, is how, for instance, Antoni Gaudí came to use these techniques for the design of the Colonia Güell Church[1], the unbuilt predecessor of the much more famous Sagrada Familia in Barcelona. Though Gaudí didn't actually use metal chains to create catenary curves – he used threads with tiny sandbags – it is no small modification from engineering to design, from using the tool afterwards in order to establish structural validity to using the tool during the design process itself. Since the latter is necessarily generative, the hanging chains have to form a system of multiple interacting catenary curves that relate directly to the design of (in this case) a church. The formula for a single catenary curve – which looks a lot like a parabola but isn't one – had already been worked out by Euler, and the design of a simple element like that wouldn't need the analogy of a model; an architect could simply use the formula to draw the necessary curve. The Güell Church, however, consists of many brick arches in various complex hierarchies, and such a system cannot be drawn by simply adding up a number of perfect catenaries. It needs both a systemacy and a procedural order, with decisions on which threads to hang first. Since the chains are flexible, we must realize that the first is constantly transforming – and all subsequent ones are continuously transforming – as we reposition and add new curves and weights. Anyone who has seen the famous hanging model with the hundreds of threads and tiny sandbags will note the striking resemblance to a typical computed wireframe model. I think we can safely call Gaudí the first computer architect.

In the 30 or 40 years after the late 1950s, Frei Otto and his team at the Institute for Lightweight Structures in Stuttgart experimented with material systems for calculating form, which were similar to the chain modeling technique Gaudí used for the Colonia Güell Church but used a much larger variety of materials. Each of these machines was devised so that, through numerous interactions among its elements over a certain time span, the machine would restructure, or as Otto says, "find form"[2]. This manner of *Formfindung* is directly opposed to "giving form," *Formgebung*, the German word for design, which implies the forcing of passive matter into shape. Most of Otto's analog machines consist of materials that process forces by transformation, which is a special form of *analog computing.* Since the materials function as agents, it is essential that they have a certain flexibility, a certain amount of freedom to act. It is also essential, however, that this freedom is limited to a particular degree set by the structure of the machine itself. In classic analog computing, most movement is contained in gears, pistons or slots, or (often) in liquids held by rigid containers, but in Frei Otto's machines, almost all materials are mixtures of liquids and solids or else start out liquid and end up solid. The material interactions frequently result in a geometry based on complex material behaviors of elasticity and variability. Some of us still tend to think materials act like Cartesian billiard balls, with full linear causality, but elasticity alone introduces much more complexity than that. Moreover, the involvement of so many agents generally shifts a system's dependency to feedback, i.e., nonlinearity, where effects change causes, rather than only causes having effects. These agents include sand, balloons, paper, soap film (which guided the design of the famous minimal surfaces for the Munich Olympic Stadium), soap bubbles, glue, varnish, and those I will discuss here: the wool-thread machines[3]. Though Otto used this technique less than, for instance, his soap film techniques, he used it specifically to calculate the shape of two-dimensional city patterns, as well as that of three-dimensional cancellous bone structure and branching column systems. Otto called these structures optimized path systems. All are similarly vectorized systems that economize on the number and length of paths, meaning they share a geometry of mergence and bifurcation.

For our purposes, we shall take a closer look at the wool-water technique, which follows an algorithmic three-step procedure:

Step 1 (figure left): Map all the targets of the system (in this case, houses) on a board. For demonstrative purposes and the sake of simplicity, the targets are arranged in the shape of a circle, but there can be any number of targets in any configuration. The points can be mapped on a supporting surface or merely on an open ring, which will give the clearest result. To ensure the basic connectivity of the system, you must connect each point to every other using wool threads. In this case, this simply means each house is connected to every other by a road. This stage of the system consists only of crossings; it is a typical surface model, a wireframe of lines that neatly make up a surface.

Step 2 (figure middle): Since we are always forced to take detours in cities, no single road ever leads straight to a single house. So in step two, it becomes necessary to give each wool thread an overlength, or slack. In this case, Otto's team decided on 8 percent, a random figure but also a generalized one, since the amount of detouring need not be averaged down to a single figure for the whole but can be differentiated throughout the system.

Frei Otto et al., Wool-thread machine generating an optimized path system between targets. *From left to right* Step 1 (system), Step 2 (overlength) and Step 3 (after wettening and self-organizing).

Step 3 (figure right): Now, dip the whole system in water, shake it carefully underwater, and take it out, slowly bringing it above the surface. The wet threads will tend to stick together, and as they begin to merge, they will lose this capacity at other points, since merging means elimination of available overlength. All overlength is processed out of the system by a surplus of cohesiveness. Since the paths come from all directions, the mergences do too, resulting in a system organized by gaps, or rounded holes, and surrounded by thick mergences of threads (sometimes more than eight) and smaller fields of crossings.

The first step contains only geometry and no materiality; then materiality takes over during a reshifting stage; and the procedure comes to a halt in a state of full geometry again, but this time, a geometry that is not imposed on the material but results from material interactions. It starts out explicitly Euclidean, but it does not end that way, because at the end there is no longer any clear division of dimensions. While we could call the first stage of the system a geometrical surface – a system in which all directions are equally present – the final stage of the model is much more complex, consisting of patches of crossings, mergences and holes. The crossing patches have two dimensions, which means that in these areas many directions are still available in the system – many lines keep crossing each other, as they do in the initial state. The merging patches consist only of one dimension, where the system takes on a single direction – multiple lines stick together to form a main artery. And the holes, of course, are areas where we lose all dimensions and no directions are available. While the first stage consists of homogeneous tiling, as in a lattice, the last stage consists of heterogeneously nested patching, as in an aggregate. The end result (step 3) is based on looseness but is itself not loose or weak but rigid and tight (when attached on an open ring, the threads come out of the water straight and horizontal!). It is a strategy of flexible, individually weak elements cooperating to form strong collective configurations. What emerges is a complex or *soft rigidity* that is very different from the top-down, simple and *frozen rigidity* of the first stage. We should therefore resist the idea that the first stage is a rigid order and the end result just a romantic labyrinth or park. The arabesque order of the end result is as rigid as the grid of the first stage but much more intelligent, because it optimizes between individual necessities and collective economy. Actually, if one were to draw lines on the photographs of the respective stages, one would find the total length in the first stage to be 100 units; the second stage, of course, would measure 108 units, but the last would measure only 85. So the reorganization results in a considerable tightening and shortening of the system. We tend to think orthogonal systems perform best, or most economically, but this is incorrect.

Frei Otto has done similar experiments with glue threads. When two sets of parallel threads, separated in two orthogonal directions, x and y, are made to touch, they don't form an orthogonal grid, as one would expect; rather, all four-legged nodes transform immediately into three-legged nodes, and the whole surface shortens considerably. Ergo, the total length of the elements in a grid of hexagons and pentagons is much shorter than in one consisting of squares. It's simply the quality of the order that precedes the quantity of the elements. Yet this is not a clear and easily legible form of order but a *vague order;* in the final wool-thread model, it is hardly possible to distinguish between surface areas, linear elements and holes. Surfaces can function as linearities, lines can cooperate to form surfaces, and holes can exist on all scales. Everything between the dimensions is materialized. And though the dimensions are clearly singularities arranging the system (the mergences into thick lines are like the ridges of dunes, which orient the sand's surface to the wind's forces), it is continuity that makes them emerge. And though the order is vague, it should nonetheless be considered very precise, because nothing is left out. There is no randomness; there is only variation.

The truly amazing feature of this system is that it is in fact structured by holes; the nesting of holes is the driving force behind its formation, though architects are trained to think that holes are, in the end, subtracted from a system. This machine does not operate on subtraction or addition but on multiplication, in the classic sense of early systems theory, which states that a whole is always larger than the sum of its parts. Here, porosity is an emergent property. The first stage (step 1) is basically *drawn*, contrary to the end stage (step 3), which is processed by a machine, *calculated*. All the singularities that coexist in the final result – all the curves, all the mergences, all the holes – are interrelated; nothing can be changed without affecting the arrangement of the whole. All the lines are mobilized simultaneously, in parallel, whereas drawing is serial, with one line drawn after the other. A drawing is always created in the visual field, while the analog machine follows a partly blind and informational logic in which the image is the end product of the process. And though this technique should be considered as a hybrid of the top-down and the bottom-up, the drawn and the generated, its intelligence lies in the fact that nothing is "translated": the drawn is not "translated" into the real. In itself, it works at full scale. In this sense, it is not even a model. This *direct proportion* is one of the main features of analog computing, which simulates not through numbers but through an empirical rescaling of the real. This brings us to an important distinction between size and scale. A model is normally a matter of *size*: it is smaller and therefore a representation of a real object. Our system is in itself real and built; its transformation into a building, city or park is purely a matter of *scale*. Scale is topological and organizational, while size is purely numerical and geometrical. In our case of the optimized path system, it is the materialization of the ink as wool *beforehand* that makes it work. The organizational and informational stage is material, not immaterial, as is so often assumed. It is the material *potential*, the material, distributed intelligence, that sets the machine in motion, in a transfer of water turbulence to wool curvature. Then it is the stickiness, the hairiness, and the curvability of the wool thread together with the cohesive forces on the water surface that bring it to a halt again and inform the end result. It is simply impossible to do this in ink. It is an intensive technique within an extensive system, and though the quantities (surface area, number of houses, et cetera) are given beforehand, the quality emerges through the interaction and multiplication of different parameters. Generally, intensiveness is a deformational property (like heating), but here it also becomes a transformational property (like boiling): the threads restructure and reorganize to "find form." The system as a whole passes a critical threshold. The degrees of freedom of deformation, which are more like extensive movements within an internal structure, become intensive, qualitative changes in the structure through transformation.

Wet Grid vs. Frozen Grid

The classic Greek lattice grid is a system that separates infrastructural movement from material structure. Simply put, the structure is that of a solid, while the movement is that of a liquid. We must consider the orthogonal grid as a frozen condition, because its *geometrical* state of homogeneity relates directly to a *material*, crystallized state of frozenness. Frozen states are simple states, and of course these were the first to be mastered by the geometricians, but to understand complex states we need to develop complex geometries. We are generally taught that geometry is the higher – the more abstract and pure – form of materiality, which is a misconception, because though geometry urges the necessary exactitude, it is totally imprecise. Any geometrician arrives after the event, when everything has dried up, and can therefore deal only with the extensive state of the material, measuring length, width and height. The wet grid, Otto's aggregational grid, is one in which movement is structurally absorbed by the system; it is a combination of intensive and extensive movement, of flexibility and motion. The geometry does not follow the event; it coevolves with materiality, is generated through analog, wet computing. One could call the organization of the final stage wet and its structure frozen, since it has come to a halt. Though it is no longer moving, it has attained an architecture of movement. In this sense, movement must be viewed as information, as pure difference, because we all know that "information," if it does not cause change, is superfluous. It simply has not in-formed, has not entered the form. This means movement in itself cannot be called information: it must be internally processed as a (temporary or permanent) transformation. Physical displacement through movement must be processed as a structural change. Basically, my argument here is that all movement as deformation is merely indexical and meaningless if it does not result in structural transformation. Movement freezes are merely *traces*, momentary stoppages of a bygone present: they are not structured through time, are not *paths* that allow movement to be repeated over and over again and slowly condense and evolve. Traces can never form a system; they are individual. Paths are collective. But paths are not *roads* either; roads are collective, all right, but not emergent, since they lack the capacity for reconfiguration. With state-controlled roads, the distinction between the field's surface material and the road's prevents the system from adapting.

Each phase of path formation should function as an analog computer for the next one. There should be enough solidification to record and enough plasticity to enable changes. This makes Otto's optimized path systems similar to contemporary multiagent computing programs based on ant colonies with their pheromone distribution. Ants have no idea they are building a complex road system around their nest; they are simply foraging, finding food and bringing it back, and meanwhile excreting pheromones. The secret behind the emergence of a path system, however, is that the pheromones evaporate within a certain period. In this way, the trails of the ants that return soonest to the nest are selected out for path usage, since their trails are the freshest and still have enough pheromones for the next group of ants to detect. Over time, we can observe an abundance of initially zigzagging radial patterns sprouting from the nest turning into a complex but optimized path system that self-tightens. This can be either a straight highway between a single food source and the nest or a more complex forking morphology with multiple foraging points. Similar multiagent systems have been translated into software packages truck drivers can use to calculate the shortest route between multiple addresses in a day's delivery schedule.

A real-time, analog computing model requires two things: a system that is internally structured (otherwise it cannot process information) and external flows of information. This simply means there are always two states coexisting, simple states and complex states, in gradation. Higher states of information can only occur within lower states of information; the two coexist hierarchically but on a continuum. They do not exist next to each other; rather, the generic and the specific share the same continuous, topological space. One always engulfs the other. We must start from a state of equilibrium that already contains information in its structure; then we need disequilibrium to increase the amount of information, and then we need equilibrium again to memorize it.

The brilliance of Frei Otto's model is that flexibility is taken literally and materially: the real movement of the water flow becomes the abstract movement of the wool structure, resulting in a coherent language of "bending," "splitting," "curving," "nesting," "aligning," "merging" and the like. All the arabesque figures in the final state of the model immediately relate to complex configurations. To understand this complexity, however, one must understand the nature of a curve. For Aristotle, any curve could be described as a mixture of straight lines and circle segments arranged in different orders. The later curve of differential calculus virtualizes both the straight line and the circle respectively as the *tangent* and the *approximative circle* that today is still an important indication of curvature[4]. In 17th-century shipbuilding, however, control of curvature was based wholly on material intelligence and not on geometry. The curves needed for a ship's hull were "lofted" at full scale using splines, thin slats of wood bent into shape with the help of lead weights. The spline is still present in all 3D modeling software, and though it now exists in many different forms, it is always based on that very important notion of materiality. Modern-day splines are the Bézier spline, the B-spline, and NURBS – it is no accident that Pierre Bézier worked for car manufacturer Renault. After shipbuilding, splines were transferred to the even more complex technology of building automobile chassis, and since car manufacturing is completely industrialized, the spline had to attain mathematical precision. A digital spline starts out straight and becomes curved as information is fed to it. The initially straight spline has an internal structure of "control vertices," or CVs, and when these are moved sideways, it takes on curvature. Therefore, the number of CVs on a line indicates the type of curvature: how far it is from straightness and how close to circularity. In short, a *geometrical* straight line going from A to B doesn't have enough structure to be moved into a state of higher complexity: moving either A or B only results in a rotation of the same straight line. The spline's prestructuring through the range of control vertices makes it *parametrical*. The only difference between a material spline and a digital one is that in the material version the overlength is external and in the computerized one it is internal. In Frei Otto's model, the wool thread going straight from A to B in the initial state (step 1) is charged in its final state (step 3) by a whole field of other influences and directions, from C to D and from F to G, et cetera; the line is taken up in a field of potentials that make it an intensive line, which is simply a curve. *A curve is an intelligent, better-informed straight line*. Keeping in mind that Frei Otto's model is a path system, this curve should be read as a road with a variable openness on which one can partly retrace one's footsteps, change one's mind, hesitate or forget. It is not labyrinthine, causing you to lose your way completely; rather, it complicates your way, makes it multiple and negotiable. A curve is a complicated straight line: it still goes from A to B, has an overall direction and takes you somewhere, but it manages other many other subdirections (tangents) along the way. It negotiates difference; it is differential precisely through connecting, through continuity. The frozen grid is always segmented and Euclidean, while the wet grid is always a continuous network, topological and curved.

Vagueness vs. Neutrality

In architecture, flexibility has always been associated with the engagement of the building with unforeseen events, with an unpredictable or at least variable usage of space. During modernism, this flexibility often resulted in an undetermined architecture, in an averaging of program and an equalization, even a generalization, of space – in short, in the transformation of an architecture of compartmentalization into one of generality and openness, seen in halls like Mies' Neue Staatsgalerie in Berlin. But we should ask ourselves: How does such generality affect the emergence of events? General, Miesian openness is only suitable when all desired events are fully programmed in advance by strictly organized bodies, as in the case of a convention center, fair or museum – when the organization of events is tightly controlled, not by the architecture but by management. A generalized openness in itself always has the effect of neutralizing events and being unproductive, because the type of space is not engaged in the emergence of events. It is flexible, of course; it is open, yes; but it is totally passive. All activity is assigned to the institutional body. The architecture itself does not engage with the way events and situations emerge; it is indifferent, neutral, with respect to this. It states that life is merely the effect of decisions already made behind the scenes, of acts that are repetitions of previous acts, with intentions that are completely transparent. The Cartesianism of the grid applies not just to its geometry but even more to the neuropsychology of the homunculus, which decrees that decisions necessitate an internal control mechanism. In its ambitions, the frozen, orthogonal grid is not very different from, say, the Miesian box or hall in architecture: it aims to find a structure that enables life, chance and change and can itself last and endure over time, spanning the unforeseen with the foreseeable. The strategy of the grid and the box has always been to average out all possible events, to be general enough for whatever happens. Now, certainly a lot of what we do is planned, and a lot of what we intend is transparent; we script and schedule ourselves all the time. But engaging with the unforeseen does not mean events are just accidents befalling our calendars.

The whole question here comes down to a study of the relationship between flexibility and movement: how does the body's flexibility relate to that of architecture? I want to argue here that extensive bodily locomotion is only possible when it is intensive first, both in the body and in the system. There is always a direct relationship between the system of motion and the internal mapping of movements in the body. Consequently, in the frozen grid, the body must act as if it is in an archive, constantly picking movements off the shelf, every act a reenaction – the body itself is a frozen grid. The wet grid views the body as a complex landscape of tendencies and habit chreodes that form grooves (lines) in less defined areas that are surfaces. All modern neurology describes the body as a wet computer, constantly evolving, adapting, practicing, managing, coping and scripting. If one follows this line of thought, the problem of flexibility is not so much "opening up space to more possibilities," as is always stated, but the concept of the *possible* itself. An event is only ever categorized as possible afterwards. The possible as a category lacks any internal structure that can relate the variations to one another; it does not produce variation by itself – it is without *potential*. The choice has always been between determined functionalism and undetermined multifunctionalism, between early and late modernism, between the filled-in grid and the not-completely-filled-in grid. But potential is something else: "Potential means indeterminate yet capable of determination ... The *vague* always tends to become determinate, simply because its vagueness does not determine it to be vague ... It is not determinately nothing" (Charles Sanders Peirce)[5]. Vagueness comes before the situation and actively engages in the unforeseen, while generality neutralizes the forces making up the situation. *Architects must replace the passive flexibility of neutrality with an active flexibility of vagueness.* In opposition to generality, vagueness operates within a differentiated field of vectors, of tendencies, that allow for both clearly defined goals and habits for as-yet undetermined actions. It allows for both formal and informal conduct. But more importantly, it also relates them through continuity, puts them in a tense situation of elasticity. The informal doesn't come out of the blue; it emerges precisely from the planned, but only because of intensive elastic planning. It is a structural Situationism that allows for *dérives* and *détournements* as structural properties. The transparent intentionality of planning and habit is stretched by the sideways steps of opaque intentionality. It does not mean the unforeseen has been successfully tamed and reckoned with: things are precisely left unplanned, but the foreseen is now structured so that it can produce the unforeseen and the new. How? Since all linearity is embedded within fields of nonlinearity, there is an enormous surplus of information in the system, a *redundancy* that allows behavior to develop in multiple ways. This redundancy is opportunistic and pragmatic, offering multiple routes toward a goal, but it doesn't afford anything to happen at any place.

At the level of design, this might be close to what J.J. Gibson has theorized as affordance[6]: a form affords certain actions and creates opportunities but doesn't determine them. Nonlinearity doesn't mean a breaking of the line, or even a relaxation that can stretch infinitely; it means a more fundamental bendability, a looping or a feeding back of the line. This means there is enough definition to allow a range of behaviors, but not so much definition as to single out one form of behavior (to be subsequently categorized as a function), nor so little definition as to make everything possible. So vagueness is not some state of amorphous indeterminacy; it is structured by singularities, by transformations in a larger field of deformations. And this applies to all architectural issues, not only the ones that relate to activity but just as much to the ones that relate to structure, since it is structure in all directions (vertical as much as horizontal) that evokes activity, be it of loads or of people. In the realm of vagueness, structure and infrastructure are continuous. Charles Peirce developed a radical rethinking of vagueness, which has been an important philosophical issue since the time of the ancient Greeks[7]. For Peirce, it all revolved around a logic of continuity. "The principle of continuity is the doctrine that our knowledge is never absolute but always swims, as it were, in a continuum of uncertainty and of indeterminacy," he wrote. "Now the doctrine of continuity is that *all things so swim in continua*"[8]. Or – even more confidently – "continuity is the great evolutionary agency of the universe"[9]. Continuity, or vagueness, understands things in the opposite way to what we know as elementary, not as prior to relations but as a posterior result of relationality. It is a universe where relationality is a given, and things – objects, beings, events – emerge from it. It accepts dimensions as much as Euclid's elements; it just doesn't accept them as discontinuous, only as generational, as sprouting from one another.

An Architecture of Continuity

The techniques invented and suggested by Frei Otto have been diverse, varying from the application of already invented techniques to ongoing projects and more fundamental research into material form-finding. Not surprisingly, his optimized path system machine is unique within his body of research, because he has hardly ever had to bother with horizontal structures. Essentially, his research has been into the complexity of the elevation, the structure, not the plan. He has always been invited to cooperate with architects who had already developed the plan, and his contribution has been in the subsequent engineering stages. We should try to develop a different agenda. Patterning effects, configurational emergent effects, happen at all stages, in both the plan and the elevation. Instead of following the plan-floor/extrusion-wall method, we should opt for a method in which elevation and plan become more intertwined and coevolve into structure. How interesting it would be to let the catenary technique generate a plan as well as an elevation, rather than merely hanging chains from prefixed points on a plan. For centuries, the order of the design process has been: first the plan (action), then structure at the corners (construction), which is finally filled in with walls (perception). Such an order, we must note, is completely Semperian, since action is the plan, or what he calls the earthwork, construction the tectonic wooden frame, and perception the woven textile walls. This must be finalized with the fire, or the hearth, which in our terminology would constitute a fourth category of sensation[10]. Our agenda should be to short-circuit action, perception and construction – which is precisely what constitutes an architecture of continuity. Getting weak textile threads to team up into rigid collective configurations is a direct upgrade or inversion of the Semperian paradigm. But they should be three-dimensional from the start: plan threads should be able to twist and become wall threads. All these techniques already exist in textile art: complex interlacings occur in crochet, weaving and knitting. The art of the arabesque is as old as architecture; it has just never been conceived at the scale of structure. And this certainly has technological reasons – the arabesque has always been accommodated by manual labor, while the straight extrusion was necessarily associated with standardization and industrialism. We should be careful, though, not to mistake the vague for "free-form architecture," or for the streamlined or the amorphous. We should strive for a rigorous vagueness, rethinking repetition within sets of variability, rethinking structures within ranges of flexibility and redundancy. The more we move towards the vague, the more articulation has to become an issue. If there is no technology of design, a technology of manufacture becomes nonsensical. With machines under numerical control, we also need the design process itself to be an informational procedure; it needs clearly stated rules and scripts to generate a structure of vagueness.

I have argued here and elsewhere that starting with the soft and ending with the rigid will offer us much more complexity in architecture. And here I am not referring to Venturi's linguistic complexity (one of ambiguity) but to a material complexity (one of vagueness). Obviously, the science of complexity has produced many diagrams of the vague, and these have often been dropped onto rigid architectural structures or typologies. That is not the way to go. Though *deconstructivism* proved successful in breaking down most of the top-down ordering tools we were used to in architecture (contour tracing, proportion, typology, axiality, et cetera), it proved totally incapable of instrumentalizing complexity itself as a material, architectural tool. It understood every act of building as an implicit counteract, a negation – and meanwhile, the engineers silently repaired it. We should, however, understand all objects as part of a process of emergence, *the made as part of the making, not the unmade*. Our goal must be *constructivism*, or emergence, and anything that emerges should coemerge. The way we see is emergent, the way we move around, the way we act in relation to others, to our habits, to our memories – all these emergent patterns should coemerge with a building's material structure. This makes our agenda one of a postindustrial constructivism, a vague constructivism. All behavior is material; all structure is material. All three constructivisms must run simultaneously, intertwined: a constructivism of form, a constructivism of seeing and feeling, and a constructivism of structure. The loads and forces working through our bodies to create social patterns are no less real than those running through columns and beams. There have been many attempts to borrow images of complexity and feed them into either circulational, formal or structural diagrams – Klein bottles, weather maps and so on – which were interesting, but not interesting enough. We should create complexity by feeding these modalities into each other through continuity. We should feed circulation into structure, feed structure into perception, and feed perception into circulation. It doesn't matter where we start, as long as we loop vagueness of action into vagueness of structure into vagueness of perception.

1. Jos Tomlow. *Das Modell, The Model* (Institut für Leichte Flächentragwerke, Stuttgart IL 34, 1989). Also in: Mark Burry, *Gaudí Unseen* (Jovis, 2007): 98–101.
2. Frei Otto and Bodo Rasch. *Finding Form: Towards an Architecture of the Minimal* (Menges, 1995).
3. Ibid.: 68–70. Also in: Frei Otto, *Pneu und Knochen, Pneu and Bone* (Institut für Leichte Flächentragwerke, Stuttgart IL 35, 1995): 174–82.
4. To better understand lines and their curvature, one can compare them to the way a car moves. A straight line, with its first-degree ("linear") curvature, holds the wheels in position. Second-degree ("squared") curvature, as in a circle, ellipse or a parabola, rotates the wheels. The third-degree ("cubic") curvature of differential calculus adds to that rotation a change in speed: during acceleration or deceleration, changing the direction of the car turns curvature into something completely different from the circles and ellipses we have been used to in architecture. After Gauss, these lines could be made into double-curved surfaces, which could be analyzed using so-called Gaussian analysis. The approximative circles (the biggest circle that fits on a point on the line without intersecting it) that fit in the cubic curves can be multiplied with one another: a sphere or balloon gives a positive Gaussian curvature, a saddle negative curvature.
5. Charles S. Peirce. *The Essential Peirce: Selected Philosophical Writings* (Bloomington, 1992).
6. James J. Gibson. *The Ecological Approach to Visual Perception* (LEA, 1986): 127–43.
7. See, for instance, Rosanna Keefe and Peter Smith. *Vagueness: A Reader* (MIT, 1999): 58.
8. Charles S. Peirce. *Collected Papers of Charles Sanders Peirce, Volume 1: Principles of Philosophy* (Cambridge, 1932): 1.171.
9. Charles S. Peirce. *The Essential Peirce: Selected Philosophical Writings* (Bloomington, 1992): xxii.
10. For a more thorough discussion of Semper's categories, see the conversation with Ludovica Tramontin entitled "Textile Tectonics" (p. 226), "The Architecture of Continuity" (p. 208), and the introduction to this volume, "Experience, Tectonics and Continuity" (p. 12).