TEN

Cutting Away from Smooth Space

Alfred North Whitehead's Extensive Continuum in Parametric Software

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> All mathematical notions have reference to processes of intermingling. The very notion of number refers to the process from the individual units to the compound group. The final number belongs to no one of the units; it characterizes the way in which the group unity has been attained. . . . There is no such thing as a mere static number. There are only numbers playing their parts in various processes conceived in abstraction from the world-process.
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> —Alfred North Whitehead, *Modes of Thought*

According to Alfred N. Whitehead, there are no numbers without group, no unity without process. But as the quotation above also serves to illustrate, Whitehead believed that there are processes of another kind that do not correspond to the world-process (the actual world). Whitehead is specifically addressing mathematical abstractions. This essay instead will address the mode of abstraction involved in the computational processing of data and in particular in the use of parametric software in architectural design. It will argue that the computational power of parametric software does not simply involve the design of space according to given sets or geometrical points, but also, and significantly for us, it relies on variables open to change in real time. Since these variables are not simply discrete units that represent points in space that are connected together, but are set to evolve in time, they have been said to be generative of space. Much contemporary debate on computational architecture has focused on notions of folding and topological evolution of forms, drawing on ontological premises of continuities and becoming.[1] This essay instead argues that Whitehead's notion of the extensive continuum can help us to rethink parametric

design as offering a conception of space based on mereotopological relations between parts and wholes.

Before proceeding to explain the way parametricism and mereotopology may oddly overlap and become the source of new speculations about the relation between discrete and the continuum, it may be useful to immediately clarify here these two key terms.

Within the field of digital design, *parametricism* refers to transformation of digital animation techniques from the mid-1990 towards an increasing malleability of data open to manipulation through scripting (use of computer code). The breaking down of geometrical figures, such as cubes, rectangles, spheres, and so on, into animate geometrical entities such as splines, nurbs, and the like, has led to spatio-temporal forms that become increasingly divided into an infinite number of variations (volume, dimensions, weight, scale, load pressure) and are interdependent and programmed to respond to external elements (such as urban traffic or weather variations) by means of adaptation. Instead of using design software tools such as CAD (Computer Automated Design) to reproduce geometric forms, parametric design starts with maintaining a dynamic link between evolving parameters and their use in form definition, enabling real-time continuous parameter space exploration through scripting. In short, parametric design points to an open mode of quantification of variables, whereby discrete parameters are not simply assembled together to produce a continuously changing form. Instead, these discrete elements are open to real-time updates thus including an infinite variety of code revisions within the computation of form. Parametricism therefore points not at a continual change of form but to a new understanding of the relation between whole—form—and parts—parameters.[2]

A specific articulation of the relation between wholes and parts is put forward by Whitehead's use of the scientific notion of *mereotopology*, derived from a combination of *mereology* (the analysis of parthood relations) and *topology* (the study of a self-connected whole undergoing continuous change). This notion became central to Whitehead's early attempts to characterize his ontology of events and explain their connection. As opposed to the primacy of a continuous becoming of form that would not account for the atomic nature of spatio-temporal actualities, Whitehead used mereotopology to explain how two events, parts (albeit complex and not individual parts), can share the region in which they are located by being co-located (by means of overlapping, conjunctions, line-to-line segmentation) rather than dissolving their parthood relations into one continuous field.

In the first part of this essay, I will focus on Whitehead's understanding of the actual world as being fundamental to his notion of the extensive continuum. This notion, however, cannot be fully grasped without a closer engagement with his mereotopological schema, which explains the fractal relation between parts and wholes. This essay claims that this schema is fundamental to Whitehead's metaphysics in its attempts at considering spatiality, measurement, division, discretization, finitude as an addition to time, temporality, duration, infinity, continuity. The second part of the essay will then address this schema as it offers to us an entry point into the conception of space that is at stake in the pervasiveness of the computational "abstraction from the world-process." The case of parametric design in digital architecture will be used to discuss an abstract form of spatio-temporality that is at once discrete and continuous. I will also suggest that parametric architecture involves not simply the generative design of spatio-temporalities through the qualitative transformations of the architectural shape, but also reveals the persistence of parametric quantities, thereby disclosing how spatio-temporalities cannot be fused together. I argue that by programming relations between spatio-temporal parts and wholes, parametricism uses a mereotopological and not simply a topological mode of design. The essay will conclude by suggesting that parametric abstraction does then not simply reduce lived temporality to coded spatiality. Instead it points at the advance of algorithmic actuality, an automated mode of prehending data defining a new form of digital spatio-temporality.

Discrete Infinities

For Whitehead, the actual world is composed of actual occasions. These actualities are grouped in events, which become the nexus of actual entities "inter-related in some determined fashion in one extensive quantum" (*PR,* 73).[3] Events therefore explain the togetherness of actualities, which Whitehead calls the "nexus." But every nexus is a component part of another nexus. The latter emerges as an unalterable entity from the concrescence of its component elements, and it stands as a fact, possessed of a date and a location (cf. *PR,* 230). Whitehead points out that the individual particularity of an actual entity, and of each nexus of entities, is also independent of its original percipient and thus "enjoys an objective immortality in the future beyond itself" (*PR,* 230). From this standpoint, Whitehead confutes the primary notions of space and time, and argues that only events, as nexuses of actual entities, are able to remain unrepeatable places with dates. In other words, actual entities are events because objects have

time and space, and yet as a nexus of entities, events go beyond this space and this time.

Whitehead's metaphysics of events does not determine objects by rendering them as the synthesis of the qualities that are projected onto them.[4] If, as Whitehead explains, each and any actual occasion is an assemblage of prehended data and prehending activities, then an assemblage is composed of parts-objects, which constitute an enduring object that acquires an epochal singularity. This singularity—which might be referred to as eventfulness—cannot be repeated, because the objects that define this singularity are partial, contextual, historical actualities. At the same time, however, if an event is a nexus of actual objects, and not the result of projected qualities, it is because it corresponds to the eventuation of unprecedented qualities that go beyond the direct projection of the actual data. But is it possible here to understand relations to be both more than effects and less than the projections of a perceiving subject? How does Whitehead avoid equating relations with projections? In particular, can the notion of prehension sustain the reality of objects without reaffirming the subjective (and phenomenological) experience of objects?

According to Whitehead, prehensions are first of all mental and physical modalities of relations by which objects take up and respond to one another. As he puts it, "prehensions are concrete facts of relatedness" (*PR,* 23). Whitehead does not start with the substance of an object or with the perception that one has of it, but confers autonomy to an actual entity's constitutive process of acquiring determination, completeness, and finitude from indeterminate conditions (cf. *PR,* 45). Although for Whitehead, prehensions are external fact of relatedness, they are not mental projections, but rather conceptual and physical relations (cf. *PR,* 245). In other words, prehensions are not only concrete ideas, but also concrete facts. This means that the actual prehension of another actual object, or of its elements, changes the internal constitution (the mental and physical tendencies) of the prehended actuality.[5] From this standpoint, prehensions also account for how actual entities acquire determination or completeness from an indeterminate process of mental and physical contagions, or from the intrusions of elements from other actual entities. Whitehead calls this process a "concrescence of prehensions" (*PR,* 24–26).

Actual entities, therefore, are not substances or indissoluble objects. On the contrary, they can become indivisible only once the concrescence of prehensions affords an actual object that then becomes the subjective form of the data prehended. This process of prehensions is thus a process of determination, and what it determines is the actuality of data defined by the

concrescence of prehensions. This is why an actual occasion is not eternal, but rather an event. It happens and then perishes. It acquires a subjective form of the prehended data and at once reaches objective immortality: it becomes an indissoluble event in time. From this standpoint, actual occasions are not effects of prehensions or mirrors of perceptions. On the contrary, they are led by their final cause to transform prehended data into a subjective form and into objective actuality (cf. *PR,* 19). The subjective form of the actual entity thus remains an objectified real potential that can be prehended anew by other actual entities. From this standpoint, the process of prehension is not a relative mechanism by which no object can as such be defined autonomously; instead, this process explains how actual entities become events, and thereby new spatio-temporal objects on the extensive continuum (cf. *PR,* 64–65).

Whitehead's process metaphysics is concerned with how indivisible or discrete unities can exist in the infinity of relations with other events, or with other actual occasions. This metaphysics does not offer us the option of simply merging or separating abstract and actual objects, but rather explains how infinity, indetermination, and abstraction infect actualities. As Whitehead puts it, "The true philosophical question is, how can concrete fact exhibit entities abstract from itself and yet participated in by its own nature?" (*PR,* 20). Each and any bit of an actual occasion strives for its own individuation by selecting or making a decision about the infinite amount of data (the qualities and the quantities) inherited from past actual occasions, from contemporaneous entities, and from the pure potentials of eternal objects. Yet prehensions are always partial, since all actual objects at once select and exclude, evaluate and set in contrast all of the inherited data. In other words, prehensions do not at all coincide with a direct downloading of data on behalf of an entity, and do not constitute objects by projecting data onto them. If, according to Whitehead, actual prehensions are the conditions of space and time,[6] and are the markers of events, it is because the indissoluble atomic architecture of each and any actual occasion is imbued with indetermination. Whitehead's process metaphysics therefore suggests that events are a nexus of actual objects. These are unrepeatable events, and yet they remain incomplete, because their objectified real potential can be prehended by any other actual entities and thus become other than it was.

From this standpoint, even if an actual object is what it is and cannot be another, it remains an unsubstantial entity. An actuality cannot therefore remain unchanged from the material corrosions of its parts; it cannot stop bursting into a sea of entropic chaos. Similarly, an actual object cannot

remain an eternal form (the form of the apple) that physically reenacts itself, and that self-reproduces itself, as does an autopoietic system. Instead, an actual occasion maintains its objective determination, involving the prehension of both actual and abstract data. To put it otherwise: actual objects are not simply dissolved into a seamless process of projections, but are instead forms of processes, forms of infinity.

Whitehead in fact rejects the idea that processes involve the continual variation of a self-modulating whole. There could be no process without forms of processes, without conceptual and physical objects prehending the infinity of actual and abstract data. According to Whitehead, a form of process precisely responds to the question: "How does importance for the finite require importance for the infinite?" (*MT,* 86). A form of process therefore explains how "each fully realized fact has an infinity of relations in the historical world and in the realm of form" (*MT,* 89). In other words, a form of process defines how an actual object reaches its completion and becomes individualized, and how infinite potentialities, or eternal objects, enter the actual spatio-temporality. A form of process explains how unexpected worlds become added to already existing objects. But this form does not correspond to the sum of objects and the accumulation of qualities and quantities of data. The concrescence of the universe involves the concrescence of actual worlds that are imbued with eternal objects. Actual objects could not become complete and there could be no event without the capacities of actual objects to fulfill the potential content of selected (or prehended) eternal objects, through which actual qualities and quantities can become other than what they were.[7]

Whitehead's metaphysics does not simply substitute empirical with transcendental causality, actualities with process, or facts with forms. Instead, it insists that there are at least two coexisting—and immanent—causes at work within an actual object: *presentational immediacy* and *causal efficacy.* Whilst the former explains how prehensions are immediately taken by the present, causal efficacy refers to the reality of the past data that lurks in the background. If causal efficacy is "the sense of derivation from an immediate past, and of passage to an immediate future" (*PR,* 178), presentational immediacy, the sense-perception of things as they are presented here and now, is what is felt at the instant of prehending. Whitehead explains that the present locus is a datum for both modes of prehension: it is an object of direct prehension according to the cause of presentational immediacy, and an object of indirect prehension through causal efficacy. In other words, the double causality does not exclude the potential in favor of

the actual, and yet does not simply merge the two causes together through material empiricism or transcendent idealism.

The two causes are two ontologies of infinity: eternal objects correspond to the infinity of ideas, and actual objects deploy the infinity of matter. It is when an actual entity selects certain ideas that a nexus becomes an event, and another actual object is added onto the extensive continuum. As Whitehead puts it, "For a continuum is divisible; so far as the contemporary world is divided by actual entities, it is not a continuum but is atomic" (*PR,* 62). In other words, for extension to become, it has to be interrupted, broken down, infinitely divided by the infinity of actual occasions selecting the infinite variations of infinities that are the eternal objects. Eternal objects, therefore, do not glue actual entities together, merging all individualities into one continual process. On the contrary, the extensive continuum as the general relational element of actual occasions is defined by "the process of the becoming of actuality into what in itself is merely potential" (*PR,* 72).

From this standpoint, the relation between eternal objects and actual entities is not simply a matter of coevolution or structural coupling, as might for instance be claimed by an autopoietic approach establishing the reversible correlation between the abstract and the concrete. Similarly, eternal objects do not generate actual occasions, but are instead "potentials for the process of becoming" of actual occasions (*PR,* 29). Eternal objects, therefore, are part and parcel of any actual entities, since the latter are precisely forms of process, and spatio-temporal structures of data. Eternal objects are intrinsic to actualities, no matter how small and how inorganic these latter might be.

Eternal objects are not the ideal continuity that link all actualities, but are indeed objects, despite being infinite varieties of infinities. Whitehead's metaphysics thus offers us an original view of infinity, which does not correspond to infinitesimal continuity between two objects, but which instead explains that eternal objects are discrete infinities nested within any nexus of actualities. It is this nesting and grappling of eternal objects inside spatio-temporal actualities that deploy the workings of a mereotopological schema, wherein actualities are hosts to an infinite number of infinities (without reaching an ultimate whole).

To reiterate: eternal objects are pure potential objects that are transformed into a real potential in time and space. Inasmuch as actual entities are causes of themselves, so too are eternal objects *causa sui*. This also means that their eternality is not grounded in substance, spirit, or life. Similarly, eternal infinities cannot be derived from finite actualities because

eternality is not flattened onto here with actual spatio-temporality. At the same time, however, eternal objects are not simply to be thought as universal qualities through which actualities relate. For Whitehead, eternal objects are ideas that are as real and as effective as any other physical thing. These ideas are at once discrete and infinite, since eternal objects are not equivalent to each other, but are instead defined by their own uncompressible infinity. Each eternal object or each idea is therefore not simply different from another. This is not simply a world of ideas: instead, each idea is constituted by infinite data that cannot be contained by a smaller entity. Eternal objects are incomputable infinities that cannot be compressed by actual quantifications (rational numbers). Instead, these nonactual worlds explain how deep connections of ideas occur between the most varied objects.[8] This is why the relation between objects is not simply given by an ideal fusion, but rather implies a fractal architecture of actual entities (indivisible sets) imbued with eternal objects (infinite quantities), worlds belonging to irreducible orders of reality, magnitude, and complexity. Eternal objects, therefore, do not simply guarantee continuity between actual occasions, because they are permanent unsynthesizable infinities that enter into, infect, and abduct actualities. Ultimately, eternal objects are not there to guarantee a continual flow or smooth connection between actualities. Instead they involve an irreversible contagion, an outburst in the continuous flow of actual relations, which corresponds to the formation of new discrete infinities on the extensive continuum of actualities.

Extensive Abstraction

Whitehead's notion of mereotopology[9] will contribute towards explaining how the computation of spatio-temporal data now includes relations among wholes, parts, and parts of parts. This implies that computational forms of abstractions are not only set to design the becoming of continuity itself, but importantly, they are also exposing new forms of becoming. In other words, the question of computational abstraction is now as follows: How can that which relates to itself become? To put it crudely, computational abstraction is now concerned with production of events: with the nexus of spatio-temporalities as these become irreversibly infected with eternal objects.

But before explaining this form of computational abstraction in the context of parametric design, it is important to clarify what is at stake in Whitehead's notion of mereotopology vis-à-vis his conception of extension and of spatio-temporal relations. In particular, it is possible to suggest that

the notion of mereotopology, because of the relation between parts and parts and wholes, can also be seen to lie at the core of Whitehead's notion of extensive continuum.

Whitehead used the notion of mereotopology to address the problem of abstraction and spatial measurement.[10] He used a nonmetrical logic to define the relations between extended parts and wholes, starting from concrete actualities.[11] Since all metrical relations involve measurement (and to measure or quantify involves a method of abstraction), Whitehead developed a new notion of extensive abstraction to problematize the general theory of relativity and the theory of measurement, which, he complained, seemingly collapsed physics and geometry into one another, ultimately ignoring the distinction between the abstract and the concrete.[12]

Whitehead used the notion of mereotopology to argue that space is composed of actual entities that connect. These entities are atomic occasions and constitute discrete events, and according to Whitehead, they explain not continual becoming but the becoming of continuity itself. Zeno's paradox of discrete units and infinitesimal divisibility is not addressed here through the Bergsonian metaphysics of a continual duration, or *élan vital,* where all quantity amounts to a difference in kind.[13] Instead, the mereotopological relation between atomic spatio-temporality reveals that continuous connection is interrupted by actual regions and subregions of relation. According to Whitehead, Leibniz's infinitesimal divisions could not define the reality of events on the plane of continuity (or the continual chain of cause and effect determining the sequential relations between actualities) because the distance between actualities could not be filled by the infinitesimal continuity of percepts and affects (cf. *PR,* 332–33). On the contrary, the distance between actual entities had to be considered in its own right: as actualities of connection, overlapping, inclusion, juxtaposition, disjunction, and intersection defined by points and lines. In other words, according to Whitehead there are always actualities amid actualities.

If Bergson's *élan vital* is a virtual continuum that is ceaselessly divided by perceptual selections or material actualities, Whitehead seems to claim that this correlation between one time (the topological invariant continuum of indiscernible, undifferentiated duration) to many spaces precludes any event from ever occurring on the extensive continuum of actualities. Similarly to Henri Poincaré's view of an infinitesimal curving space or a topological continuum of uncut forms, Bergson was seeking a temporal invariant between events.[14] From this standpoint, only *virtual* time (uncoordinated intensive time) can *amodally* link two causally connected actualities (or parameters). Such virtual time is a real interval that exposes the

plenitude of cosmic time, and has no intrinsic measure except a continual variation of differential relations.

Whilst rejecting the idea that infinitesimals could be used to explain the relation between actualities, Whitehead also argues that these relations should be compared not to the infinite lines of the Euclidean parallel axiom, but rather to finite segments (cf. *PR,* 328). Each actual occasion is finite, and does not change or move. Actual entities are real potentialities, determined by what Whitehead called causal efficacy: the sequential order of data defined by the physical prehensions of past data from one entity to the next (cf. *PR,* 169). From this standpoint, continuity is explained by the connection between entities, which are not geometrical points, but rather "spatial regions" with semi-boundaries (e.g., volumes, lumps, spheres) (cf. *PR,* 63; 121–25; 206). Hence, continuity is not given by the convergence of two parallel infinite lines touching infinity, but by the actual relation between spatio-temporal regions of objectified real potentialities (actual entities): slices of time, atomic durations.[15] Instead of infinitesimally divisible points of perception and affection, Whitehead believes that there are an infinite number of actual entities between any two actualities, even between those that are nominally close together. This is why Whitehead rejects Zeno's paradox of infinitesimal small points and argues that continuity is not a ground to start from, but something that has to be achieved as a result of the extensive connections of actual entities (cf. *PR,* 97–97; 294).

In "The Relational Theory of Space"[16] Whitehead explained his method of extensive abstraction as the interconnection of different levels and scales of actualities. With the concept of extension, as opposed to notions of absolute space,[17] Whitehead claimed that relations were part of the concrete order of things. But how does a connection between actualities become a relational actuality, a blind spot or space-event? To answer this question, we need to delve deeper into Whitehead's mereotopological schema. According to the latter, actualities, in the process of their formation, select eternal objects or pure potentialities. Through doing so, they cause the continuum of actualities (or the extensive continuum) to split into events: atomic occasions of experience that change the nature of the continuum itself. In other words, the continuum becomes other than it was each time actual entities prehend eternal objects, the ingression of which corrupts their structure and organization. This is how actual entities become objects of contingency. As Whitehead specifies, "in the essence of each eternal object there stands an indeterminateness which expresses its indifferent patience for any mode of ingression into any actual occasion" (*SMW,* 171). Eternal objects are inter-

nally determined by infinity, but are externally related to actual entities, as the latter's indeterminate possibilities (cf. *SMW,* 160).

It may be important to specify here that eternal objects are not an undifferentiated pool of qualities that are divided or spatialized by actual entities. On the contrary, it is important to rethink eternal objects in terms of discrete infinities, which do not define the external relation between actual entities in terms of infinitesimally smaller points of conjunction (e.g., Leibniz's percepts and affects, Deleuze's differential or intensive gap, or Bergson's duration or virtual time). Eternal objects, therefore, are not temporal forms of relations, but are permanent and infinite quantities that are isolated from their individual essences. They are relata in the uniform schema of relational essences, where each eternal object is located within all of its possible relationships (cf. *SMW,* 164). Whitehead explains that there is a uniform scheme of relationships between eternal objects, which is precisely defined by the impossibility of reducing their infinite quantities by subsuming them under a smaller or integral cipher (i.e., the one, God, or being). Instead, eternal objects remain isolated from each other, embedded as they are in their own infinity. Nevertheless, whilst eternal objects are indifferent to the extensive continuum of actual entities, from whose standpoint eternal objects are pure indeterminacy, they nonetheless acquire an unprecedented togetherness once they are included in an actual entity, and thus gain an individual essence—a certain quality of infinite quantities. This means that for any actual occasion "a," there is a group of eternal objects, which are, as it were, the ingredients of that actual occasion. Since any given group of eternal objects may form the base of an abstractive hierarchy of relation, there is an abstractive hierarchy associated with any actual occasion "a." This associated hierarchy is "the shape, or pattern, or form, of the occasion, insofar as the occasion is constituted by what enters into full realization" (*SMW,* 170). This formal hierarchy thus defines the unity of eternal objects in actualities.

Despite the fact that the order of eternal objects, as pure relata, is not open to modification by spatio-temporal actualities, these objects are nonetheless part and parcel of the eventful becoming of such actualities. In particular, and insofar as these otherwise noncommunicating eternal objects are selected by actual entities to accomplish their "subjective aim," they also acquire unrepeatable unity in actual entities. This unity reveals how eternal objects are also subjected to the irreversible formation of events (or nexuses of actualities) and, indeed, change within the order of actualities (where pure potentiality or indetermination becomes real or determinate

potentials). This also means that space-events are at once disjunctions of actual data and conjunctions of eternal objects.

According to Whitehead, eternal objects are internally related to each other only in terms of "a systematic mutual relatedness" wherein each eternal object has a particular status in relation to other objects (*SMW,* 161). Therefore an eternal object "stands a determinateness as to the relationship of *A* [an eternal object] to other eternal objects" (*SMW,* 160). This determinateness suggests that these objects are not fused into one continual eternal form. On the contrary, they are eternal only because they are infinite. Yet they do not share the same kind of infinity. There is no equivalence between the status of an eternal object and another eternal object. Eternal objects are not externally related to each other but only to actual entities, which select them as they grow and change. However, eternal objects also explain the atomistic character of actual entities: their nonrecursive spatio-temporality, which constitutes a slice of duration. The relations between actual entities therefore neither correspond to a mechanical chain of cause and effect and nor can they simply be granted by a metaphysical continuum, a transcendental time described by the infinitesimal degrees of being. Instead, relations are spatio-temporal actualities, and define events as an irreversible disjunction within the order of actualities and a unilateral conjunction of eternal objects. From this standpoint, the extensive continuum of actualities that determines their material ground of sequential connection and recursive calculations splits itself into thousands of quantities, the asymmetrical reassemblage of which becomes a nexus of actualities or a space-event. The extensive continuum is, to say it with Deleuze and Guattari, schizophrenic.

Computational Quantities

Whitehead's mereotopological schema can thus contribute to seeing the computational abstraction of concrete relations under this new light. I will now discuss how this mode of abstraction has become central to digital design, and in particular, to *parametricism,* which Patrick Schumacher has claimed to be the new global style for architecture and design.[18] As an instance of computational abstraction of concrete relations, I argue that digital parameters need to be conceived in terms of actualities, spatio-temporal divisions that are forming a new algorithmic matrix. In particular, Whitehead's mereotopological schema offers us an entry point into the increasingly smaller divisions or partitioning of time, a micro-quantification that is able to calculate the gap between one state and another, or the rela-

tion between states. Whitehead's mereotopology resolves the question of partitioning of continual temporality by suggesting that between states there are always an infinite number of actualities, actual regions and subregions of actualities. With parametricism, the dynamic partitioning of the gap between points exposes the persistent function of parts and of the relations between parts, in which wholes are nothing more than parts that connect. These parts—in this case, parametric quantities in computational programming—are discrete entities that change values at different places according to different degrees of relations established by the program and the environmental input, due not only to their capacity to select data that come from the actual ground, but also to their capacity to be infected by data that they are not able to compute. As noted above, this aspect of parametricism can be explained through Whitehead's notion of mereotopology, because the relation between parts and parts and wholes can be seen to lie at the core of his notion of extension or extensive continuum.

Whitehead's mereotopological schema rejected the Leibnizian infinitesimal series and questioned Bergson's predilection for temporal continuity by arguing that what connects points are actual entities on an extensive continuum. Whitehead's mereotopological schema provides an apposite means of suggesting that there is no ontological or metaphysical equivalence between computational abstraction and the world-process. Instead, Whitehead's mereotopology also serves here to suggest that algorithmic parameters, like numbers, are dynamic agents playing their parts in the formation of an algorithmic matrix of infinite spatio-temporalities. The latter are not representations of an actual world of data or of actual spatio-temporal experience that can never be fully quantified. Instead, the digital—and parametric—process of abstraction of physical data cannot but correspond to proliferation of algorithmic or parametric actual entities that cannot be fused with or incorporated by what we know of space and time.

At the core of the mereotopological view of the extensive continuum, there is a persistent nonreciprocal relation between parts and the whole, so that the continuous partitioning of the continuum on behalf of increasingly smaller actualities imposes the view of a constant fractional matrix, never coinciding with its parts. To this end, mereotopology does not reject but insists on the significance of division and quantification in the production of spatio-temporal actualities and new occasions of experience.

Whilst topological continuities are expressions of large assemblages, and these assemblages are able to incorporate discontinuous events into a stream of infinitesimal variations, mereotopology instead accounts for the unalterable encounter between parts and between parts and wholes. From

this standpoint, an algorithmic parameter is not only the transduction of physical qualities (such as the volume of a space, gravitational forces, the circulation of air, the movement of people, the shades of light, the sonic frequencies, electromagnetic vibrations, etc.) into finite quantities, but is an actual object itself. Furthermore, the relation between parameters is itself a spatio-temporal actuality that is not visible to the terms of the relation. This is because the abstract potential between parameters cannot be grasped at the level of sequential sets, but needs to be explained as the infinite quantities of abstract relations that infect and add novelty to the actual order of parameters. This means that topological continual relation is only one way of articulating the relation between parts and wholes. The mereotopological schema between eternal objects and actual entities offers another way.

The dominance of topological approaches to explain the relations between parameters is demonstrated for instance by Lynn's calculus-based architectural forms. Here it is that the qualitative relations of vectors constitute space as a fluid environment of forces. Yet this insistence on the capacity of parametric design to account for the dynamic and infinitesimal relations between points, resulting into the proliferation of curving surfaces and morphogenetic forms, corresponds to the temporal design of space, where the capturing of movement defines digital architecture in terms of time. This anti-Euclidean proposition of space has led to the formation of "parametric urbanism" concerned with the inclusion of approximations and emergent qualities that cannot be exactly measured (i.e., approximations to a point) into planning. By conferring fluctuation and movement to the geometrical form as a whole, digital architecture has incorporated the qualitative dimension of the gap between points, the percepts and the affects, into the digital design of temporal space. The ingression of topological connectedness between points has thus resulted in an automated process, whereby algorithms are constantly transducing temporal qualities—affects and percepts—into approximate quantities, thus developing an aesthetic of continual quantities of qualities.

The critique of computational modes of quantification contends that instances of the latter (such as parametricism) are yet another form of measuring the qualitative character of relation. Nevertheless, to argue that computation mainly entails a transduction of qualities into quantities (albeit approximate quantities) is to deny that quantities could ever be more than finite sets of instructions. Yet Whitehead's mereotopological schema adds an abstract schema of infinite objects to the actual continuum, so that the infinite quantities cannot be discerned from qualities. Points of con-

nection are not only finite parts that overlap: the process of overlapping includes the selection of abstract quantities that add a new quantitative character to parts that are already overlapped, and thus reveals the formation of a new actual entity. From this standpoint, I want to suggest that parametric relations are not only transductions of qualities into quantities. They are infected with abstract, non-denumerable quantities, or rather eternal objects: discrete yet permanent infinities that add novel data to the relation between existing parametric processing. From a mereotopological point of view, each parametric extensive relation is hosting another order of quantities that cannot be contained by the number of its actual members.

The topological model implies the permanent ground of movement from which events emerge qua events only when it becomes possible for actualities to jump out of the spatio-temporal grid into the infinity of virtual time. The mereotopological schema suggests instead that events are the cumulative order of spatio-temporal actualities hosting an unrepeatable togetherness of eternal objects. Therefore it is not the formal hierarchy of eternal objects that determine actual events. Instead, events are the result of the actual accumulation of physical data, the causal chain, which is interrupted by the irreversible ingress of eternal objects. These objects are not simply selected by actualities to manage orders of behavior or action, but are prehended for the pure chance or potentialities that these objects offer. Actualities therefore do not simply operate a probabilistic calculation about which eternal object to select. On the contrary, the selection for nonactual ideas involves the ingression of chance into what has happened, what may happen, and what could have happened. This is how contingency becomes intrinsic to the formal architecture of eternal objects: a process by which existing relations can change and fashion themselves anew. This means that the indeterminacy of eternal objects is prehended like the irreversible reality of chance; they offer pure potentialities, and thereby determine the atomic (and eventful) character of actual relations.[19]

If the topology of parametric design implies the continuous calculation of variables, Whitehead's mereotopology, by contrast, always subtracts actual events from overall continuity. Mereotopology therefore suggests that underneath continual morphogenesis there lies a space of random quantities or infinite numbers that cannot be counted as such. These are the black holes that are inherent within probability and statistical calculation and that remark the occurrence of *an infinite variety of infinities* immanent to the actual regions of a nexus of occasions. In parametric design, this space perforated with holes is defined by the intrusion of parasitic data,

the surplus of codes that are unable to be united under a morphogenetic continuity.

The parametric design of buildings, cities, environments, and objects does not simply involve the algebraic manipulation of physical data. Instead, the computational abstraction of the extensive continuum of actualities (resulting in parametric relations) involves the addition of chance to actual relations. Parametric design thus confronts those discontinuous infinities constituting finite quantities. This discontinuity explains how the spatio-temporal continuum can become other to the actual relations that compose it. Here, the introduction of novel configurations of space is not derived from the continual variations of form, but from universes of infinite quantities that abduct the actual relations of data, infecting any set of probabilities. If topological continuity involves qualitative transformations, mereotopological discontinuities expose the eruption of uncompressible quantities breaking through any smooth surface. Instead of criticizing computational abstraction as the mere (and reductive) measuring of qualities, this essay suggests that parametric design deals with unsynthesizable orders of quantification (finite and infinite relations), and in consequence it cannot avoid becoming a channel for the proliferation of indetermination within the programming of extensive relations.

Whitehead's mereotopological schema of parts and wholes thus offers another view of the computation of relations that lies at the heart of digital design, and of parametricism in particular. The relational space of data processing is defined by the actuality of the relation, whereby the sequential order of actualities is infected with abstract objects, the indeterminate reality of which adds new character to existing patterns of actual relations. This is not to say, however, that contingent physics is ontologically grounded in the order of eternal geometry.

Mereotopology exposes parametricism to the indeterminate, contingent infinities of urban programming, where abstract quantities add a new level of determination to parametric relations. From the standpoint of mereotopology, these infinite quantities are parts that connect or disconnect with the processing of sequential parameters (considered as a whole). At the same time, this whole processing can also be a part that connects to another. Parts therefore are not the components of a whole, but remain random objects that have the power to change the extant order of actualities.

Following the logic of cause and effect, the relation between parametric data involves a movement from past spatio-temporalities to those of the present and future, all of which are restricted by the physical level of parametric design. Here extension, as Whitehead reminds us, is not the realm

of measure, but "the most general scheme of real potentiality" (*PR,* 67), since "all actual occasions are internally and externally extensive,"[20] and are related by means of extension—or, in this case, by parametric quantities, which are veritable actualities amidst the others.

For instance, multi-agent systems,[21] such as BDI (Belief-Desire-Intention) agents,[22] are probability models that operate not through pattern recognition (or according to the connectionism of neural networks), but by developing tendencies and attitudes that lead to thought-actions. Multi-agent systems are not only informed and generated by the interaction between agents and by their local capacities to learn and adapt, but are able to evolve certain inclinations instead of others. These systems can be conceived as forming a nexus of actual entities,[23] and as thereby crafting new possibilities of actual relations. Multi-agent systems are able to prehend[24] (to borrow a term from Whitehead), select, and reactivate variable quantities (changeable and evolving parametric relations) derived from past and simultaneous parameters. In short, multi-agent systems are finite entities composed by the prehensions of both their internal relations (defined, for instance, by the evolving dynamics of genetic algorithms using past data to reengender information) and their external connections, which determine the extensive relationship between parameters. Multi-agent systems are therefore proactive entities that select and rearrange their internal relations and acquire a subjective unity (a subjective form in Whitehead's terms) by which they can ingress the world's external relations by prehending other elements and entities. It is precisely this process of prehension, selection, activation, and assemblage of data that links Whitehead's mereotopological schema of extensive relations to parametric urbanism.

Multi-agent systems for instance point out that endorelations within systems already enjoy a series of external relations of variables. Here a variable becomes part of another cluster of variables, which in turn changes the pack of variables it originated from. In other words, parametric design exposes how endorelations within sets of variables and series of exorelations are faced with irreducible subvariables, which are those irreducible parts that can be detached from the computational design of the whole. Therefore, if we take the relation between a set of parameters A and a set of parameters B, the subsets of A and B are not simply fused in the relation C, but become a new object: a new parametric set equipped with new tendencies, singularities, and powers proper to C. C is not simply the link between relata, but becomes a set of data itself, autonomously establishing new conditions of possibilities not only for C but also for the autonomous subsets of A and B. This is why the coming of C does not mark the disappearance of

the A and B subsets, but the extension of their real potentialities in C. If the individual and autonomous subsets of A and B become part of C, because their potential tendencies exceed the local connection between A and B, they are however not neutralized in the whole object C, but retain their unaltered indivisible singularity (or subatomicity). It is however important to bear in mind that according to Whitehead, actual entities—the regions and subregions of A and B—do not endure forever. These entities must exhaust their own set of relations, reach completeness or satisfaction, and thus perish in order for C to become objective data for another set of variables—just as C inherited objectified data and the real potentialities of relations from A and B.

Similarly, the parametric software adaptive structure corresponds to the physical, extensive connection between actual entities, the fusion and integration of parts into wholes. But, this is only the topological level of parametric design. However, a mereotopological reading will have to include another level of relationality, the overlapping and intersection of subatomic parts by means of other parts *(mereology)*. In other words, the relation between the distinct planes of actuality implies not their merging but rather their simultaneity as revealed by the actual regions and subregions of intersection, that is, the actuality of the relation itself.

It could be argued that parametric design involves at least two modes of potentialities that define each and any level of actuality. These modes correspond to Whitehead's distinction between the real potential of each actual entity to become the datum of another and the pure potentials (or eternal objects) that enter actual occasions at many points (*PR,* 23). From the standpoint of mereotopology these modes imply at least two orders of magnitude: the order of finite quantities and the order of infinite quantities. This is to say that Whitehead's distinction between the real potential of actual entities and the pure potentials of eternal objects returns in parametric design as the automation of actual relations, as finite and infinite quantities.[25] The computation of relations therefore reveals the presence of an alien spatio-temporal system that intersects the digital design of spatio-temporalities: the advance of space-events or new actual forms of infinite quantities as internal conditions of the parametric order. It is therefore possible to argue that there are computational events corresponding to the actuality of spatio-temporal systems that are irreducible to both the physical and the digital binarism of extension. In the next section, I will discuss the event in terms of automated prehensions and thus clarify what a computational event—or nexus of actualities—can be.

Automated Architecture

Drawing on Whitehead's method of abstraction, it is possible to consider parametric design in terms of an algorithmic process of prehension by which space and time are derived from the ordered world of parametric programming through the transmission of data from the past to the present. From this standpoint, a programmed environment is entangled in a process of parametric prehension, whereby past data enter into a relation with the data of the present. This defines the arrival of novelty not as something that depends on the subjective impressions of interactive users, but rather as involving the parametric prehension of data—a prehension that derives its own regions and spatio-temporal extensions from already programmed sequences.

If parametric urbanism marks the programming of extensive relations, it truly involves the automation of prehensions, and thus a new level of determination of space and time. In other words, digital urbanism is adding a new spatio-temporal system onto the extensive continuum of actualities. Parametric urbanism includes rules for selecting, contrasting, and adopting data from previous sets so as to calculate present and future quantities of relations. It thus entails that parameters can become calculative engines relying on their prehensive capacities to connect variables across different orders. This is not due to a free, unbounded power that parametric design has to generate change in architectural models (i.e., the generative evolution of genotypes forming infinite versions of the same shape). On the contrary, if parameters are not simply executors of commands, it is because they are prehensive operators nesting data within a set, selecting and transforming quantities, and establishing actual nexuses between parameters of various scales and dimensions.

Digital parameters therefore are automated modes of prehension insofar as they are also modes of decision-making that do not simply correspond to the binary states of 0s and 1s. On the contrary, parametric design now implies the computation of continual or topological relations, according to which relations have become objectified, datified as actual entities. Parametric design thus requires no preplanned modeling, but step-by-step procedures of decision-making, according to which the path of the sequence can be reordered in real-time. The prearranged order of parameters therefore remains open to counterdirections derived from the short-term power of decision acquired by automated relations in the process of computation. The computation of relations thus requires that preplanned decisions become substituted by prehensive capacities of decision-making, which afford

the parametric system the freedom to establish unintended connections between parameters within the constrained conditions of sequential programming.[26] As Whitehead argued, freedom derives from the power of decision, which implies that an actual entity (a parameter or nexus of parameters in this case) reaches its final cause (or subjective form) by transforming the data received into finite sets of rules. Actual entities can decide the extent to which they can enter in a relational composition with other entities, and in doing so, they exercise a power of freedom or autonomy. This means that not all sets of variables must enter into relation with all parameters encountered in the process, or that some changes in their arrangement are negligible and do not lead to a space-event. In other words, parametricism maintains no overall dictum according to which everything must be connected or kept in a constant state of change. Whilst it is true to say that there is no emptiness between parametric sets, there are at the same time indeterminate degrees of relatedness depending upon the actual prehensions involved.

From this standpoint, one could argue that parametric urbanism may be conceived as a mode of programming extension that is driven by software-prehensive capacities of spatio-temporal division, and not by the topological invariant that gathers all spatio-temporalities into a continuous varying whole. The parametric automation of prehensions does not simply quantify urban qualities of relations, but is set to design the quantitative relation between parameters involving the selection of abstract quantities in the construction of a soft urbanism.[27] Thus the parametric programming of temporal and environmental changes—physical variables, such as humidity, temperature, wind, air circulation, the movement of people, and so on—also involves the design of the causal efficacy of actual entities, the prehension of the physical data of the past that is inherited by the present sequential processing of variables. Even when physical data are introduced into the program in real-time, it is still a matter of how these data from the past are prehended by parameters within the present. This is because the parametric programming of weather variables, for instance, organizes the prehensions of spatio-temporal configurations precisely as the registering of change from one state to another. In short, I suggest that the programming of physical variables coincides with the automated prehension of variables, which result in the registering of change from the past to the present. On the other hand, however, parametric probabilities are not mere representations of physical variables, but rather become a present counteraction on the inherited past.

Parametric design thus also implies the automation of both physical and conceptual prehensions through which data from the past is not simply inherited but transformed in the present. As such, conceptual prehensions define the mental pole of an actual entity (in our case, a parameter or a set of parameters) and its power of decision-making. This latter is informed by the selection of eternal objects, indeterminate quantities infiltrating the arrangement of probabilities in the process of computation. Since parametric relations coincide with spatio-temporal forms of process, potentialities and possibilities built upon regions and subregions of relations, the sequential calculation of probabilities cannot but admit indeterminate quantities in a programmed sequence of rules. These quantities define the actuality of the relation not only in terms of temporality but also, and importantly according to Whitehead's mereotopological schema, as extension. The relation therefore corresponds to an invisible space split from point A and B and yet it explains how A and B can be simultaneous without becoming fused into one. The computation of relations therefore involves the constitution of a new actuality that is reducible neither to the combinatorial mode of digital parameters nor to the interaction of physical variables within digital programming.

From this standpoint, the mereotopological schema offers a strange understanding of parametricism, according to which the latter corresponds to the computational abstraction of relations showing that parameters themselves acquire actuality as they enter into a spatio-temporal nexus. These actualities can be understood here as computational space-events. Events, according to Whitehead, involve the capacity of any actual entity to select and become affected by pure data-objects (or eternal objects in Whitehead's terminology), which define how the indeterminate becomes determinate in any actual entity.

Whitehead's mereotopological schema implies that events come first. Events are the summation of actual entities in a nexus of actualities, which has been infected by an infinite variation of data that have come together for the first, unique, and unrepeatable space-time. From this standpoint, it is possible to contrast the topological view of parametricism, which assumes that variations are to be derived from the relational or *infinitesimal space* of contingencies that lie outside the system (and are then programmed within the urban model, for instance), with the mereotopological insistence that parts, quantities, and discontinuities exist not only at the level of actualities, but also at the general level of formality. This means that Whitehead's mereotopological schema forces us to revisit the computational

significance of formal hierarchies in relation to actual contingencies. Contingencies are no longer to be conceived as external to the formal schema (i.e., as a mere factor of extrinsic force); instead, it is here argued that contingency or chance are in fact internal to any formal processing—that they are parts of that formal process that nonetheless remain incompatible with the whole process. This means that patternless quantities—incalculable data—are the unconditional matrix of any logic of computation. As a result, they define the incomputable starting point of any mathematical, physical, or biological order, as well as of the order of culture.

From this standpoint, parametricism can be criticized not for being too abstract, but for not being abstract enough to accommodate the view that indetermination is to be found first of all at the level of formal computation, because it is there that parameters encounter the indeterminate conditions (patternless data) for which they can become eventful. This idea of computational indetermination is based on the mathematical logic of randomness (i.e., lack of structure), whereby "something is random if it can't be compressed into a shorter description. In other words, there is no concise theory that produces it."[28] This notion of randomness is strictly derived from Gregory Chaitin's algorithmic information theory, pointing at the centrality of infinite infinities or of incompleteness within axiomatics to show that randomness corresponds to the maximally unknowable data within computation. Since it is impossible to calculate the size of the smallest program, as Turing and Gödel demonstrated, Chaitin concludes that computational logic implies a program-size complexity, whereby it is the program (the software, the theory, or formalism) and not just its application that shows the existence of patternless infinities, which drive decision-making within any algorithmic set.

Similarly, I have not used the example of parametricism to claim that novelty in computation is to be derived from external factors, or for instance from means of interaction between software and hardware, which supposedly explains, according to some designers, how digital urbanism can develop dynamic planning able to adapt to infrastructural variations. This is not what is argued here. Instead, my argument is driven by the possibility offered by the mereotopological schema of finding the conditions for novelty in the digital conception and programming of spatio-temporality. I suggested that the discontinuous architecture of eternal objects corresponds to the infinite varieties of infinities (whereby there is no ultimate plane to engulf them all) and not to the continuous variations of a whole (as represented by the topological model of continuous transformation of shapes). Eternal objects therefore are not just eternal qualities of objects,

such as the intensive qualification of a chair that constitutes *chairness* (the capacity of the chair to function as a seat). On the contrary, taking inspiration from Whitehead's mereotopological schema, I argue that eternal objects are infinite varieties of parts that acquire relational continuity only once they enter, are selected by, or infect actualities. Hence, a whole as a relational continuity is a discrete unity, a part that exists in this actual entity and not in any other. In other words, a whole is neither smaller nor bigger than its parts but is split into parts that do not necessarily communicate with one another (i.e., they do not communicate by means of a principle of sufficient reason).

This essay has perhaps forced an unnatural juxtaposition of the formal level of randomness (patternless data) with the formal schema of eternal objects. But this forcing is not arbitrary. It is simply a means of arguing for the underestimated significance of infinite varieties of quantities in the computational method of abstraction and in particular in the programming of spatio-temporality in digital architecture. It is suggested here that the nonnegotiable power of random data (i.e., data that cannot be compressed in an elegant theory, theorem, or program) is the very unconditional condition for a novel formalism of digital space that does not simply extend software to an interactive relation with hardware or with the physical environment. From this standpoint, mereotopological discontinuity is not conceived as an alternative to the topological transformation of space, which is ontologically grounded in relational continuity. If anything, the mereotopological schema of discontinuous data can help us to address the randomness of a computational event. The latter instead requires that indeterminate data become decisional quantities in the cumulative processing of nonequivalent actualities. These indeterminate data are not simply subsumed within an extant (albeit changing) process. Instead, they define spatio-temporal events, which arrive and perish, without constituting a continual surface of variation.

To put it in another way: the topological ontology of parametricism implies that the event is programmed before it can happen, thus flattening novelty (or event) onto a topological matrix of continual coevolution, reciprocal presupposition, or structural coupling. Yet against this, and whilst borrowing from Whitehead's mereotopological schema of relation, it is possible to suggest that parts do not become a whole: instead, parts (e.g., eternal objects) are infinite infinites that join together and become a whole (the unity of eternal objects in actual entities) that itself remains a part (an actual entity) that connects to another (actual entity). This is also to say that if the topological aesthetics of parametricism harnesses events in its

own morphogenetic body, mereotopology reveals that the computational abstraction from the world implies the eventuation of new actualities, breaking spatio-temporalities that characterize the becoming of the extensive continuum: the arrival of a new spatio-temporality out of sync with the entire system of relations *qua* smooth variations.

Against the metaphysics of the whole (Being, Time, or God), Whitehead's mereotopology suggests that the relations between actualities are to be explained by other spatio-temporal parts. Similarly, I propose that the critical reading of digital architecture cannot reduce computational abstractions to already programed and finite productions of spatio-temporalities. Instead, I claim that the digital parts are derived from the unconditional non-denumerable infinities or by the ontological power of randomness. Since digital architecture capitalizes on the capacity of relations to smooth edges and permeate boundaries, it seems important to engage with the question of relationality itself in order to demystify the dominant role that topological continuity has acquired in describing the ontology of extension. In particular, I argue that the insistence on the temporal quality of relations and thus the inclusion of real-time and contingent variations within planning through parametric software is being underdetermined by the infinite quantities that disrupt the order of parametric relations.

From this standpoint, parametricism (or the computational abstraction of relationality) is not simply another instance of the smooth environment of ubiquitous digitality. On the contrary, parametricism can instead be taken to suggest that the smooth surface of continuous variations is in fact exposed to computational interferences, blind spots, or space-events that cannot be compressed in finite quantities.

Events, therefore, do not grant continuity between entities, but on the contrary are the occasions for the discontinuous becoming of the continual order of actualities. This explanation however only helps us to describe the actual level of novel spatio-temporality. Actual novelty instead does not come from nowhere, and does not exclusively concern the physical realm. Novelty must also be explained at the level of abstraction, or in our case computational abstraction. The mereotopological schema of eternal objects and actual entities proposed by Whitehead affords metaphysical support to what in information theory is increasingly becoming unavoidable: the presence of the randomness at the heart of formalism. This formal reality of randomness (the fact that non-computable data are now an 'unknown probability and not an impossibility for computational programming) is here taken as the unconditional condition that makes any mode of computation (analog or digital) possible.

This unconditional stance has to be found within the computational processing of algorithms, at the formal and axiomatic level. It is suggested here that random data can reveal a strange contingency within form, or indeterminate chance within programming. From this standpoint, randomness interrupts the topological coevolution and interactive modes of continuous adaptation between the use of urban software and urban behavior. Far from establishing a continuous feedback or reversible function whereby software takes command over urban behavior or the latter acts back on the program, the sequential running of algorithms instead inevitably confronts the infinite quantities of rules for each quality of behavior, which result in the proliferation of unprovable and inapplicable computational spatio-temporalities. It is my argument that randomness triggers contingency within computational rules and, in the particular case of parametricism, in the digital design of urban space.

This new dominance of contingency within programming demarcates the unquantifiable reality of an abstract space-event and the impossibility for physical space to be one with these events. In particular, digital urbanism is invaded by computational events that are at once discovered and constructed by the software programming of actual spatio-temporalities. From this standpoint, parametricism is a case in which the digital design of time and space is not simply set to program the emergence of events, but is instead unleashing unlived spatio-temporal relations into the urban worlds of the everyday. These space-events are symptoms of the concreteness of digital architecture, which, it is now clear, can never absolutely match the physicality of actual space. I do not consider this mismatch to be a failure. Instead, it points at a schizophrenic and nonreversible situation whereby the programs used to organize urban infrastructure are constructing and/or revealing an infrastructure of another kind, thereby exposing the all too real realm of data-volumes, data-density, and data-architecture.

Notes

1. Greg Lynn, "Architectural Curvilinearity: The Folded, the Pliant and the Supple," *Architectural Design* 63, nos. 3–4 (March–April 1993): 22–29. Kipnis Jeffrey, "Towards a New Architecture," in *Space Reader: Heterogeneous Space in Architecture,* ed. Michael Hensel, Christopher Hight, Achim Menges (London: John Wiley & Sons, 2009), 112. Giuseppa Di Cristina, "Topological Tendency in Architecture," in *Architecture and Science,* ed. Di Cristina (New York: Wiley, 2001).

2. For specific examples about parametric architecture see "Digital Cities," special issue, *Architectural Design* 79, no. 4 (July–August 2009): 1–135, i–iii; "Material Computation: Higher Integration in Morphogenetic Design," special issue, *Architectural Design* 82,

no. 2 (March–April 2012): 1–144, i–iii; "Computation Works: The Building of Algorithmic Thought," special issue, *Architectural Design* 83, no. 2 (March–April 2013): 1–152, i–iii.

3. For instance, a molecule, as a moving body, experiencing local changes is not an actual occasion, but a nexus of occasions and thus an event.

4. This argument against Whitehead's process metaphysics can be found in Graham Harman, *Guerrilla Metaphysics: The Carpentry of Things* (Peru, Ill.: Open Court, 2005), 82–83.

5. Ibid.

6. As opposed to the universal and absolute conceptions of space-time, Whitehead argues that the mutual prehension of things defines the very condition for spatiality. For instance, in the concert hall, the mutual prehension of the volume of sound, the forms of instruments, the distribution of the orchestra, the mathematical analysis of each momentary sound, the musical score are all implicated in the experience of an immediate specious present. See *MT,* 84.

7. Whitehead points to a double movement (and causality) of form and process, which requires actualities to become infected with potentialities, atomic entities to be related by means of potential divisions of their continual relations (*MT,* 96–97).

8. Whitehead specifies that an eternal object is "any entity whose conceptual recognition does not involve a necessary reference to any definite actual entities of the temporal world" (*PR,* 44).

9. Whitehead used mereotopology to explain the spatialization and temporalization of extension. See *PR,* 294–301.

10. The analysis of parthood relations (*mereology,* from the Greek *mero,* "part") was an ontological alternative to set theory. It dispensed with abstract entities and treated all objects of quantification as individuals. As a formal theory, mereology is an attempt to set out the general principles underlying the relationships between a whole and its constituent parts, as opposed to set theory's search for the principles that underlie the relationships between a class and its constituent members. As is often argued, mereology could not however explain by itself the notion of a whole (a self-connected whole, such as a stone or a whistle, as opposed to a scattered entity of disconnected parts, such as a broken glass, an archipelago, or the sum of two distinct cuts). Whitehead's early attempts to characterize his ontology of events provide a good exemplification of this mereological dilemma. For Whitehead, a necessary condition for two events to have a sum was that they were at least "joined" to each other, that is, connected (despite being or not being discrete). These connections, however, concerned spatiotemporal entities, and could not be defined directly in terms of plain mereological primitives. To resolve the bounds of mereology, the microscopic discontinuity of matter (and its atomic composition) had to be overcome. The question of what characterized an object required topological, and not mereological, analysis. From this standpoint, two distinct events could be perfectly spatiotemporally colocated without *occupying* the spatiotemporal region at which they are *located,* and could therefore share the region with other entities. The combination of mereology and topology contributed to Whitehead's articulation of the notion of the extended continuum. See Roberto Casati and Achille C. Varzi, *Parts and Places: The Structures of Spatial Representation* (Cambridge, Mass.: MIT Press, 1999), 13–17, 51–54, 76–77; and *PR,* 294–301.

11. An occasion of experience, according to Whitehead, implies a certain unique togetherness in experience. See *PR,* 189–90.

12. In particular, Whitehead used the notion of mereotopology to suggest that the mathematical-geometric order had to be separated from the physical world so as to explain their relations formally, by making measurement as determinate as possible. According to Whitehead, the general theory of relativity equates the relational structures of geometry with contingent relations of facts, and thus loses sight of the logical relations that would make cosmological measurement possible. This is why Whitehead's mereotopological approach insists on the spatialization and temporalization of extension, whereby "physical time is the reflection of genetic divisibility into coordinate divisibility" (*PR,* 289). Whitehead argued that the solution to this problem was to separate the necessary relations of geometry from the contingent relations of physics, so that one's theory of space and gravity could be "biometric," that is, built from the two metrics of geometry and physics. See *PR,* 283–87; 294–301; 327–29.

13. In particular, and contrary to Whitehead, Bergson's theory of time, the qualitative time of the *élan vital,* is opposed to the metric time of scientific epistemology, thus identifying the necessity of abstraction with the imperatives of the scientific enterprise. Whitehead, on the contrary, seeks to separate geometrico-mathematical abstraction from physical actualities to propose a more rigorous metaphysical schema of relations. See Henri Bergson, *Creative Evolution,* trans. Arthur Mitchell (New York: Random House, 1994), 358–65, 374–80.

14. Henri Bergson, *Matter and Memory,* trans. N. M. Paul and W. S. Palmer (New York: Zone Books, 1991), 133–78.

15. As Whitehead explains, each actual entity is atomic as it is spatiotemporally extended. See *PR,* 77.

16. Alfred N. Whitehead, "The Relational Theory of Space," trans. P. J. Hurley, *Philosophy Research Archives,* no. 5 (1979): 712–41.

17. In the relational theory, Whitehead discussed the connection between points and objects as a causal action occurring between atomic units not in the spatial dimension, but only in the temporal (*PR,* 37). However, the method of extensive abstraction or the extensive continuum mapped the interrelated structures of events according to a geometry that deployed the uniform relatedness of nature, especially of spatio-temporal relations and the topological priority of events. Modern topology distinguishes between many different types of connectivity (connected, locally connected, pathways connected, and so on). Whitehead's mereotopological model of the extensive continuum instead specifically concerned the interrelation between the actual occasions that define the spatio-temporal order of nature. See *PR,* 148.

18. Patrick Schumacher recently claimed that parametricism is the dominant style of today's avant-garde, characterizing the power of large-scale urban schemes. See Patrick Schumacher, "Parametricism: A New Global Style for Architecture and Urban Design," *Architectural Design* 79, no. 4 (July–August 2009): 14–24.

19. As Whitehead specifies, "In the essence of each eternal object there stands an indeterminateness which expresses its indifferent patience for any mode of ingression into any actual occasion" (*SMW,* 171).

20. As Whitehead observed, actual occasions are the entities that become and thus constitute a continuously extensive world. In other words, whereas extensiveness becomes, "becoming" is not itself extensive, but atomic. The ultimate metaphysical truth

is atomism. The creatures are atomic. In each cosmic epoch, according to Whitehead, there is a creation of continuity. See *PR,* 35, 77.

21. Multi-agent systems are composed of interactive intelligent agents used to solve problems and make rational decisions spanning from online trading, disaster response, and the modeling of social structures. See Ken Binmore, Cristiano Castelfranchi, James Doran, and Michael Wooldridge, "Rationality in Multi-Agent Systems," *Knowledge Engineering Review,* no. 3 (1998): 309–14.

22. The Belief-Desire-Intention (BDI) software model is a program for Intelligent Agents using the notions of belief, desire, and intention to solve problems in agent programming. Chang-Hyun Jo, "A New Way of Discovery of Belief, Desire, and Intention in the BDI Agent-Based Software Model," *Journal of Advanced Computational Intelligence and Intelligent Informatics* 7, no. 1 (2004): 1–3. Inspired by Michael Bratman's theory of human practical reasoning, where intention and desire are considered as pro-attitudes (mental attitudes concerned with action), the model focuses on problem-solving concerned with plans and planning, and does not just allow the programming of intelligent agents. Michael Bratman, *Intention, Plans, and Practical Reason* (Cambridge Mass.: MIT Press, 1999). According to Manuel DeLanda, these multi-agent systems develop an attitude towards the meaning of sentences, propositions, and semantic content. For instance, the belief and desire of agents can change and develop a new attitude towards sentences, which leads to a new set of consequences for the workings of the system. BDI agents, as opposed to neural nets that operate on pattern recognition and extraction, are susceptible to language. The field of parametric design, according to DeLanda, needs BDI agents to model complex urban conglomerates, but it can also benefit from cellular automata to model specific and complete levels and scales of spatio-temporal interaction. Hence, it is only through the interaction of a population of models that specific domains and their singular levels and scales of interaction can be fully designed. See Manuel DeLanda "Theorizing the Parametric," paper presented at University of Southern California conference on "Intensive Fields—New Parametric Techniques in Urbanism," Los Angeles, December 12, 2009; see podcast at http://arch-pubs.usc.edu/parasite/intensive-fields/video-archive/.

23. Whitehead's notion of a nexus of actual entities may be particularly relevant to describe the architecture of multi-agent systems, which is based on the nexus between variable quantities composed by internal relations and external connections. In particular, actual entities are finite units and have an extension in space and time. Whitehead also calls actual entities "microscopic atomic occasions" (*PR,* 508), by which he means that actual entities enter a process of concrescence moving from an initial status or facts (or for instance an initial variable quantity) coinciding with a macroscopic view to a final status or fact (or a changed quantity) defining the microscopic view. In other words, an actual occasion reaches a subjective unity, becoming a final fact through its concrescence. Thus actual entities are divisible but undivided. Actual entities perish, terminate, and become complete quantities through a process of internal division and external connection that forms the architecture of a nexus, involving the development of actual entities in time with all their changes. Similarly, multi-agent systems can be conceived as a nexus of finite actual entities, variable quantities acquiring a microscopic unity.

24. Whitehead's abstract scheme defines prehension (or relation within actual entities) as marking the genetic division of the extensive continuum. This means that pro-

cesses are generated by relations within actual entities via the notion of inclusion (or genetic division) and between actual entities via overlapping or external connectivity (coordinate division and strains). See *PR,* 114–15.

25. On the categorical distinction between pure and real potentialities, see *PR,* 23.

26. The divergence in the trajectory of a path from its initial conditions characterizes the physics of chaos and complexity theory. Whilst deterministic chaos is, like every empirical phenomenon, entirely determined in principle by linear cause and effect, chaos physics has pointed out that the cause of chaos cannot be traced back in a linear fashion. From the standpoint of far-from equilibrium dynamics, there is no deterministic efficient causality for all the particles in the universe. As Shaviro points out, such a position violates Whitehead's ontological principle (that everything actual must come from somewhere) and the reformed subjectivist principle (that everything actual must be disclosed in the experience of some actual subject). Hence, even God is not omnipotent, but subjected to restrictions. Steven Shaviro, *Without Criteria: Kant, Whitehead, Deleuze, and Aesthetics* (Cambridge Mass.: MIT Press, 2009), 17.

27. Marco Vanucci, "Open Systems: Approaching Novel Parametric Domains," in *From Control to Design: Parametric/Algorithmic Architecture,* ed. Michael Meredith, Tomoto Sakamoto, Albert Ferre (New York: Actar D USA, 2008), 118.

28. Gregory J. Chaitin, *Exploring Randomness* (London: Springer-Verlag, 2001), 18.