Topological Thinking: Digital Systems in Landscape Urbanism

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Abstract: The contemporary large-scale megalopolis is complex, full of inconsistencies, economic oscillations, mixed-hybrid forms, and ever-changing environmental consequences. If our urban territory embodies imbalanced heterogeneity, how can we confidently design resolutions to offer such flexible results? Borrowing models found in mathematics, *topology* – a configuration of point sets or properties remaining invariant through transformational states – might offer clues for continuous states of urban metamorphosis. Observing the horizontal urban domain topologically elastic, conformed to a sub-set of limits, can activate design decisions within such inconsistent circumstances. Using a series of case study sites in one of the largest cities in the world, Shanghai postulates an urban setting packed with paradoxes of continuously broken behaviors. In the realm of contemporary landscape urbanism practices, this paper suggests methods of combining *topological* space and *topographic* extensivity for modeling and designing the future city.

Keywords: Landscape architecture, urban design, non-deterministic systems

1 Introduction

Inherently systems of ecologies, landscapes manipulate both productive agricultures and support scenes of developmental and economic forces operating in the city. Particularly within the city, the horizontal fabric engages in systematic processes beyond infrastructure and utility. "By substituting the terms form-structure-function with information-system-interaction, these eco-scapes investigate new frontiers of eco-bio-logical writing on the artificial, characterized by an open, dynamic nature, sensitive to the surrounding world" (GREGORY 2003). Rightfully described, our megalopolis today provides an incredible, and extremely complicated environment not only to design, but also systematically interact. Importantly, our landscapes can provide opportunities of engagement with existing multiplicities without a complete 're-wiring' of the urban code. If this were true, it would be relevant to understand the circumstances, which define such complex interactions. How can these unplanned, unpredictable negotiations truly become embedded within our processes of design? If designers can expose the elaborate codes built into the cities landscape and reject idealistic and arrogant orders of 'control', we may just be able extend the behavioral systems found in already established topography. Intentionally we can decipher the codes of the existing state not as products of form, but extracted relationships. Contrary to popular ideas in "bio-mimicry", "bio-philia" allows for analysis of systems and behaviors beyond the superficial duplication of form. By extracting the so-called, 'codes' mentioned above, and translating point-sets of urban behavior into newly engaged design and planning processes, master planning has the potential to become less abrasive and increasingly flexible. The following examples attempt to demonstrate *topological* thinking methodically to continue the behaviors of uncovered existing configurations in complex urban interactions.

Although this research work is on-going, the length of this paper allows for only a brief introduction into two provisional themes (1) *the urban topology* – the behaviors of point-

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sets on a contiguous urban topography, and (2) *the morphological landscape* – a design method capable of negotiating with existing and future possibility states.

2 The Urban Topology

2.1 Point-Set Topology and Behavior

We need to define the basis of the term *topology*; not to confuse *topology* with *topography*. Both terms derive from the root *topo* – meaning "place" or "local". *Topography* describes the arrangement of features on, and the relief from, a surface. *Topology* in mathematics defines continuous transformations from one geometric object into another. Examples of *topology* in complex geometries include manifolds, Mobius strips, and even nicknamed the "rubber sheet geometry". Relationships between deformed states can become *topologically* equivalent (HATCHER 2005). When the geometry transforms from one state to another, and no point sets added or taken away, the assembly reconfigures new plausible deformations; stretching, twisting, bending, and distorting. A rubber band transforming from a square to a circle is a common example. It may seem difficult to understand beyond this introductory level. The basic use for us here stresses the gap between differing geometries and their relationships of equivalency. Especially useful, these relationships in certain geometries change – or stretch – to other states while the properties and interactions remain inter-connected.

Relating the urban condition to *topological* interactions can become quite powerful; whether consistently connected or not. Deciphering relatively small changes of elastic moments in the urban realm, hypothetically we begin finding and anticipating larger constituents held within the city. For example, in *topological* functions, by identifying smaller collections of *topological* interactions, the generation of extended *topology* can be inferred. If this is true, then it may be possible to identify urban behaviors based upon smaller unplanned interactions. Thus, developing an accurate reading of built form and transformable patterns at the larger, urban scale. Consider for a moment the pattern of neighborhoods. Changes incur constantly and seem to continuously distort relationships found in *topological* equivalences. Although these neighborhoods inherently remain made up of the same components, or point-sets, the relationship between smaller sample collections have the ability to alter the larger *topology*. Before moving into specific case study sites in Shanghai, we test geometrical possibilities in the realm of topological mathematics. First, within a finite 3-dimensional field a random set of points distribute (I). This initial point field follows simple rules for creating the subsequent topography. Secondly, the algorithm inputs the initial points (I) and moves into a second position (II). The position II also generates its own topography. Easily digestible, these first two stages obtain relatively predictable features of folding and elasticity in the topographic outcome. We searched for the position in-between, if there is in fact such a state. It is here where we find unpredictable consequences of the two differentiated states (Figure 1). The third phase contains influences from both states I and II. This highly complicated topography successfully produces an output of both/and folded phase states (DELEUZE 1993).

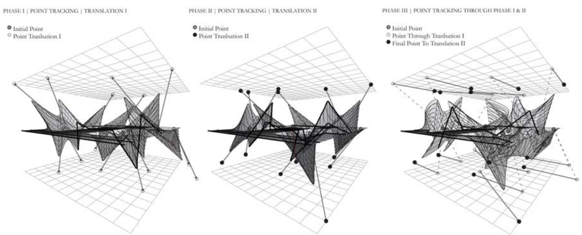

Fig. 1:
Point tracking model simulating topological limits, geometrical memory, and phase transitions

The phase III of the study above might lend to strengthen ideas in the formal manipulation of memory. Positions in point sets (I) and positions in point sets (II) use the same quantity, only now in a new position. This junction allows for "overturnings, hybridization, mediations, and interactions" and accepts "deterritorialization as continuous reproblematization and the in-between as heterogeneity and agreement of opposites" (GREGORY 2003). When considering indications of behavior and memory, the positions themselves are not critical. The space between positions contains the greater influence amongst the global relationships. It is precisely in this realm the design work described below attempts to maintain.

2.2 Paradox of Topological Space and Fragmentation

If geometrical objects remain equivalent in *topology*, then the spaces between each state hold wide spaces of possibility, termed *topological space*. Oddly, topological spaces created from "objects for which continuous functions can be defined … are not very geometrical at all" (HATCHER 2005). This space is complex because it tends to be general in terms of mathematical equations. For our efforts here, we use the term to identify the "non-geometric objects". Similar to the alterations of *topology* – in effect, between states – "considerations of the landscape, as the phenomenology of a dislocated sensibility" (GREGORY 2003) anecdotally suggests landscape is made by multiplicity of dislocated states. Ironically this notion of dislocation can assist in our definition of possibility space. Analogous to the studies examined previously in phase I and II defined topological states – the topography noticeably links to the point set distribution. And once we include the "transitional" state in phase III, the information embedded into the *topology* increases exponentially. "The extra structure often presents fascinating local questions. In a Riemannian manifold, for instance, the curvature may vary from point to point" (GREGORY 1997). In other words, if the topography embraces multiple positions, then the "data" or even "memory" becomes stretched. Therefore, the geometry created does not contain one or the other, but includes both point sets. "When manifolds (local *n*-tuples of real numbers) occur 'naturally' in a branch of mathematics, there is always present some extra structure" (HIRSCH 1997). These structures tend to be binary operations, dynamical systems, and conformal structures. The differential *topology* determining local interactions of point sets in a structure detect global boundary, or *topological limits*. This paradoxically captures the essence of transformations in the city. To clarify how this all may become applied when analytically mapping, we have identified three study areas in Shanghai (Figure 2). Although each of the three sites differ in function, density, and location, they share similar behavioral morphology; in this case, fragmentation. Each of the areas seems to rapidly change configurations, even between our brief sample sets. Interestingly, we find here the urban topological limits – the break in the continuously morphed urban *topology*.

Fig. 2: Growth / decay patterns in Shanghai: (a) Huangpu (b) Yangpu, and (c) Pudong

Landscape architect James Corner designates “field diagrams or maps describing the play of those forces are particularly useful instruments in furthering an understanding of urban events and process” (CORNER 2006). Our mapping studies here attempt to reveal such hidden processes. The survey map of Huangpu, Yangpu, and Pudong areas above highlight development patterns from 2000 to 2015. Similar to our exercise in phase transitions through the point tracking simulation and Corner’s ideas of field mapping, the patterns reveal point sets capable of topological equivalency between temporal states. Again similar to before, the temporal states only offer portions of the story. The relationships between states of exchange become meaningful. Even though represented geometrically in pattern, the input affecting such metamorphosis and memory between states exposes opportunity for a rich *topological* space.

In the Huangpu area, research shows a decrease from the year 2000 of 22,351,387 m^2 to 2015 of 9,288,603 m^2, approximately 60 %. This type of behavior happens to be consistent in the other sample sets. For Pudong, the actual size of reduction, of about 40 %, also obtains a significant percentage rate compared to Huangpu. Describing these transformations in an abstract definition, 60 % of *topological limits* have been reached through 15 years of temporal memory. Certainly abstract, though the notion of 60 % fragmented memory could be included in the urban design strategy. Majority of historical master plans fail to recognize such deterritorialization and transference behavior when developing future plans for the contemporary city. Although the master plan has its own logics, rules, and fiscal interests, is it possible for the urban designer to capture and employ memory through the translations of topological states? The fact remains we know very little about how the city transforms. Big data can distinguish major shifts in rapid development patterns amongst the massive megalopolis. Even the broken segments of the city are undoubtedly reflections of some consistent feature. This consistency raises a new paradoxical underpinning of this work – while unable to precisely determine real estate and fiscal patterns 50 years in advance – we do have the opportunity to design non-deterministic topologies, proficient enough to absorb the inconsistencies in the projective future.

3 The Morphological Landscape

3.1 Re-emerging Negotiations

Continuously since the conception of 'landscape urbanism' coined by Charles Waldheim, we find central themes of landscapes performativity in the design process. James Corner describes methods of contemporary landscape through four provisional themes; "processes over time, the staging of surfaces, the operational method and the imaginary," (CORNER 2006) describe systematic processes, not fixed states of horizontality. Out from the four themes, the first three distinctly define methods of continuity and adaptability. Portrayed in the mathematic model above, this approach explores such methods while continually providing digital feedback loops to investigate possibility and unpredictability arranged in the *topological space*. Upon exploring the city's *topological* milieu, controlling the clarity of digital system interactions generate intensive landscape results. The processes of the studies from above shift into hyper-models of urban implementation. The variable configurations and adaptable simulations transpire into effective morphological systematic processes of exchange.

Pairing the mathematical differential *topology* with Corner's first two themes *processes over time* and *staging of surfaces*, our analytical model moves into responsive competence. Corner states processes of over time "addresses accumulation, deregulation, globalization, environmental protection" and become the shaping of urban relationships *and* the spatial forms of urbanization (CORNER 2006). To take on prospective future processes, here we model with the same rule sets analyzed from previous growth / decay mapping patterns. To overtly exaggerate this point, our modeling processes continue evidences found from growth / decay behavior in the site-specific environments. And alternatively compete against the introduction of external forces, e. g. popular new urbanism models. The *topological space* between temporal states emerges into flexible process between growth and decay. The passive system navigates into and through possible states.

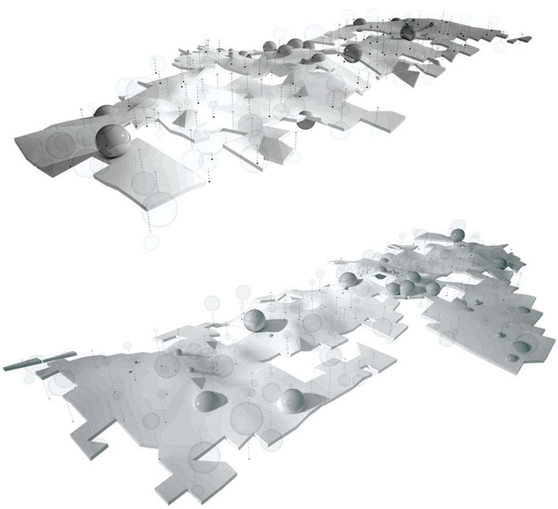

Fig. 3:
Topological simulation articulated by point sets and fragmented thresholds found within study site in Shanghai. (a) *above*, possibility state I and (b) *below*, possibility state II.

The example above zooms into a manageable scale compared to the large sample sets. The models attempt to exploit the *topological* continuity and the often under-utilized broken urban fragments to describe future possibility states (Figure 3). Positioned in the same plane and location, the simulations identify two spaces of topological possibility, state I and state II. Each state reflects upon the previous and future states to stitch together through stretching, morphing, and expanding the topological space provided. Remember, the topological equivalency from mathematics allow for the continuity between transformed states, thus attempting to inform direct connections between urban memory and morphology. Achieving both continuation and uncertainty, the models consider "the formal and material articulation of infrastructure, coordinating its operations with the territorial processes, forms and parameters identified in the indexing of site, developing its relation to the ground, and elaborating its architectural composition" (CASTRO et al. 2013). Possibility states expand and compositions replace the fiscal and developmental approach in an effort to encourage processes of uncertainty (Figure 4).

Fig. 4:
Testing topological simulation in urban surface; negotiating within the existing context and promoting future prospective

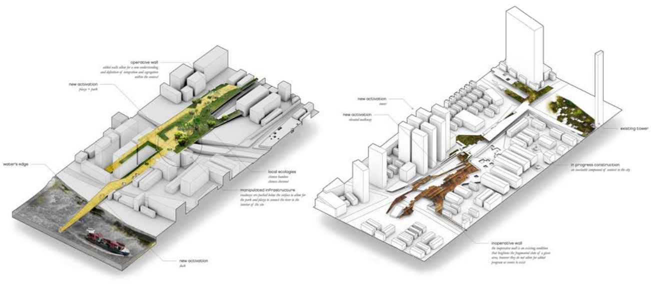

Fig. 5:
Differential topology samples deploying fragmented planning activities distributed in Puxi, Shanghai

Staging of surfaces, borrowed from Corner, requires recognition of contextual responsiveness. In other words, the activities employed in the master plan must also sensitively accommodate existing local integrity while simultaneously operating along an unpredictable future. Promoting healthy environments through the navigation of such fragmented *topological* extensivity makes for a rich and tightly inter-connected urban configuration (Figure 4). The varying degrees of surface implementation accumulate and divide when necessary along the temporal milieu. Treatment of the surface includes recombination of local ecologies, manipulation of infrastructures (connecting into the city-scale systems), and acknowledging established municipal and capital markets targeting new construction projects (Figure 5).

3.2 Topology to Inform Ecological Sensitivity

Shanghai lies within the boundaries of the Tai Lake basin. Due to its geographical situation, during the rainy season, the lake overflows and discharges water through a series of rivers, creeks, and streams. The water flows west towards Shanghai's numerous water systems and feed into the most significant outlet, the Huangpu River. A combination of major pollutant contributors severely affecting the Huangpu River and its ecological tributaries include agricultural waste, sewage discharge, and industrial dumping. Over 80 % of Shanghai's waterways affected, making it the most polluted waters in the world. In addition to the major problems of pollutants, unstable soil conditions of native marshlands attribute to the city's ecological breakdown. As the city expanded, developments filled these waterways and obstructed the natural watershed paths. Is it possible for the differential *topology* space, as modeled previously, transformable enough to stage a new healthier environment? Briefly described here, employing ecological continuity in a speculative topological model can further support the reclamation of natural marshland ecologies through horizontal manipulation. Based on the sample site situated along the Huangpu River, this proposed topological maneuver alleviates water pollution in a five-stage filtering process (Figure 6).

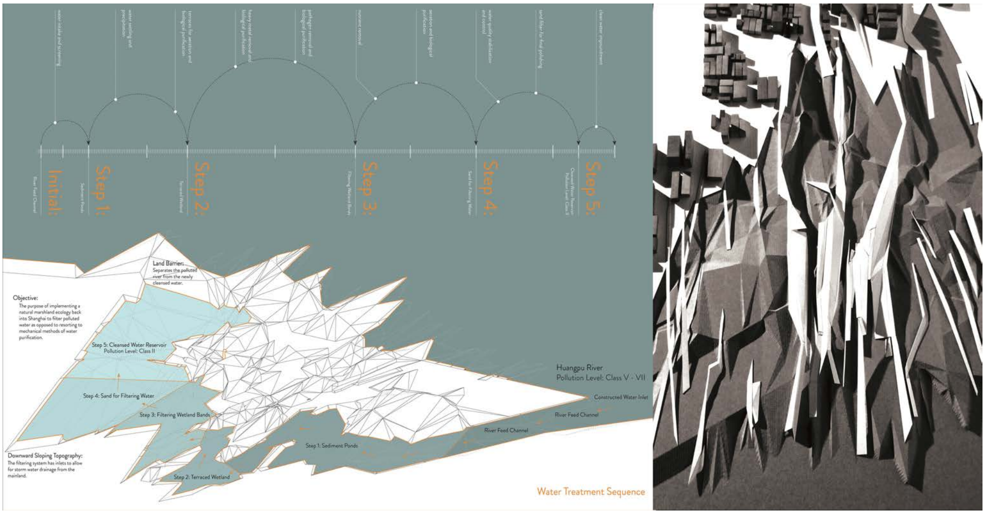

Fig. 6: Water filtration topology embedded in Puxi along the Huangpu River. Configuring existing context and promoting memory of the marshland ecology; filtration-sequencing diagram (left) and physical model (right).

The staging of constructed wetlands manipulates the horizontal plane and critically establishes morphogenetic growth patterns including extensive possibility of future reductive sequencing. Five-stages manipulate topography and control *topological* oscillations. The parameters within the topography inform a space of propagation and possibility of "processes over time" to include the participation necessary for staging the water cleansing process. To put bluntly, the manipulations informed by ecological processes formally articulate phase changes between stages – thereby maintaining *topological* equivalency. Thus, the investigative strategies tested in this work use methods in landscape urbanism to diagnose existing themes of self-generative adaptions. A focus on evaluating where and how the opportunities for horizontal extensiveness can be implemented set the stage for process rather than product. The projected systematic model evolves into an urban ecological schema. Mutual interventions between existing site conditions and the performativity of topography intertwines a series of paths, corridors, overpasses, tunnels, and platforms leading people to the permeable edges of filtering pools. Intentionally, this model simulation reinforces the argument against the drivers of capitalistic development methods and allows for fertile urban behavior, whether supporting growth or decay as implied in earlier research. The proposal samples the potential for re-introducing marshland ecologies in facilitating the elimination of Shanghai's water pollution epidemic. Thinking topologically establishes a continuously connected and flexible urban landscape.

4 Conclusion

Our work perceives the city and landscape similar to GroundLab's "natural processes that constantly change and evolve, therefore requiring flexible and adaptable mechanisms" (CASTRO et al. 2013). The "mechanism" enables us to observe the city as a series of differentiated *topological* spaces. Designers have the opportunity to work with not knowing in mind. It is arrogant to think the urban designer understands the city in full capacity. This work challenges the discipline in translating analytical knowledge of the city behavior and considers *thinking topologically* both for the behavior of urban unpredictability and promotion of evolving ecologies. This means, knowing the point sets – via capital development growth, neighborhood gentrifications, demolition patterns, ecological complications, and the unpredictable states "in-between". Differential *topology* of the horizontal urban surface empowers local interactions capable of continuous metamorphosis. Definitions of *topology* combined with landscape topography stimulate elastic modeling in speculative urban design thinking.

References

CASTRO, E., RAMIREZ, A., RICO, E. & SPENCER, D. (2013), Critical Territories: From Academia to Praxis. LISt Lab, Roverto, Italy.

CORNER, J. (2013), "Terra Fluxus. In: WALDHEIM, C. (Ed.), The Landscape Urbanism Reader. Princeton Architectural Press, New York.

DELEUZE, G. (1993), Fold. Translate by Tom Conley. The Athlone Press, London.

GREGORY, P. (2003), New Scapes: Territories of Complexity. Birkhauser, Basel.

HATCHER, A. (2005), Notes on Introductory Point-Set Topology. Cornell Univ., Ithaca.

HIRSCH, M. (1997), Differential Topology. Springer, New York.