控制与不确定性：
对原型思维范式的展望

CONTROL AND UNCERTAINTY: TOWARDS A PARADIGM OF PROTOTYPING

1 引言：模型、控制与不确定性

“景观的非人类属性及其文化构建之间，以及人类对自然的敬畏和对其进行利用、管理与控制的冲动之间，总是存在着矛盾。”[1] 景观设计师在对生命系统和物质进行设计时，经常会遇到意料之外的情况。那么，原型概念将如何帮助设计师应对设计中的不确定性?
I Introduction: Model, Control, and Uncertainty

“There is always a tension in landscape between the reality and autonomy of the nonhuman and its cultural construction, between the human impulse to wonder at the wild and the compulsion to use, manage, and control.”[1] Designing with living systems and materials, landscape designers always have to deal with unexpected outcomes. What insights can the idea of prototype provide to address the issue of uncertainty?

Oxford English Dictionary defines the term of “prototype” as “[t]he first or primary type of a person or thing; an original on which something is modeled or from which it is derived; an exemplar, an archetype”[2]. The term was first popularized in industrial design and software engineering to denote the first machine or the first piece of program that was built to prove the concept. A prototype possesses a twofold quality: On the one hand, a prototype is a type of model, which has a kind of metaphorical relationship between one thing and another; On the other hand, a prototype also carries a sense of realism that is beyond a metaphor. This twofold quality makes prototype a special type of model that can transform people’s understanding of the tension between control and uncertainty.

However, rooted in the western means-end chain relationship, prototypes have always been overlooked theoretically and historically. In the western philosophical tradition, one envisages an ideal form (eidos) as a model, and then the model can serve as a goal (telos) and, at the same time, an end that calls for actions. As French Philosopher Francois Jullien puts forward that “with our eyes fixed on the model that we have conceived, which we project on the world and on which we base a plan to be executed, we choose to intervene in the world and give a form to reality.”[3] This means-end chain can be observed in every aspect of contemporary environmental practices. For example, in the past few years, the means-end chain has been used in the design of complex urban environments. The means-end chain is a tool for designers to evaluate the effectiveness of a project. This evaluation process is based on the means-end relationship, which is a way to tie the "mechanism" and the "effect" together. Finally, although people want to project an ideal model on the world and develop means to achieve this end, unexpected circumstances will always arise to undermine the action and control regime of any plan. Thus uncertainty denotes those events that are outside the predictions allowed by the conceived model[3].

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environmental discourse. Myriad of research initiatives, such as smart cities, propose to embed sensing networks in the environment to produce more data. Then, the environmental data feeds into Machine Learning (ML) algorithms to build Artificial Intelligence (AI) systems. Finally, these AI systems, or models, are distributed in the cyberphysical systems to manage all kinds of environmental processes, such as stormwater control[4]. However, trapped in a means-end relationship, this framework only conceptualizes uncertainty as model-environment difference that needs to be reduced one way or another. In the means-end chain, human’s relationship with the future always revolves around the tension between control and uncertainty.

Landscape theory and practice in the past decades have provided a body of work that challenges the means-end chain and the role of models in environmental practices[5]. These practices highlight the value of prototypes as a special type of model that does not fit within the means-end chain. This paper uses landscape practices to articulate the values of prototypes in the environmental discourse, and argues that with prototypes, model-making can be envisaged in such a way that is no longer on the line of reducing uncertainty but about providing a wide range of possibilities. Thus, our relationship with the future is transformed from the tension between control and uncertainty to anticipation and hope, which is crucial when humanities are faced with environmental challenges such as climate change.

Since the idea of model and the tension between control and uncertainty have always been central to the field of cybernetics and systems theory, it is crucial to re-examine how the idea of prototype was articulated in the development of cybernetics and systems thinking. Contrasting a body of landscape works and the three waves of cybernetics movement shows that the contemporary system-based landscape design framework does not fit within the means-end that is entailed by early cybernetic principles; Instead, landscape design can provide an alternative understanding of model-making on the line of prototyping.

This updated understanding can help parse out the concept of prototyping in the cybernetics movement and unearth a family of “cybernetic creatures,”[6] including Norbert Wiener’s “the moth” and “the bedbug,” and John von Neumann’s cellular automaton, as prototypes in the cybernetics movement which has been overlooked within the means-end chain. These cybernetic prototypes can be juxtaposed with a case study in landscape design—a hydromorphology table experiment conducted at the Responsive Environments & Artifacts Lab.
2 Background: Cybernetics and Landscape Design

Cybernetics is an interdisciplinary field of study that started in the United States since the 1940s, when a team of post-war intellectuals, including engineers, mathematicians, anthropologists, and ecologists, converged on a new theoretical model based on systems thinking to understand control and communication between mechanical and biological systems. The core concern in the field is about how to control different systems through feedback mechanisms to mitigate uncertainty. It is only in recent years that scholars have started to pay attention to the influence of cybernetics principles on landscape design. It is argued that cybernetics concepts instilled into the landscape discipline via ecological sciences and arts in the 1960s, and Ian McHarg and Lawrence Halprin were two prominent figures who established the link between cybernetics and landscape design.

However, because of the interdisciplinary nature of cybernetics, its concepts were instilled in every aspect of intellectual life in the 20th century as systems theory has prevailed across disciplines. Many ideas such as feedback, coupling, and autopoiesis that were initially developed in the field of cybernetics have been imported into disciplines such as Sociology, Computer Science, Systems Theory, Ecology, and Humanities, all of which are fields where landscape architects have been drawing inspirations. Thus, it can be simply recognized that, since the 1960s, cybernetics and the issue of control and uncertainty have been “in the air.” This paper contrasts the cybernetics movement with landscape design theory and practice since the mid-20th century and highlights the idea of prototyping in both fields that help landscape architects rethink the issue of uncertainty.

Katherine Hayles schematized the development of cybernetics as three waves of research mobilizing among different fields of study. The first wave of research, commonly known as first-order cybernetics, speaks to the Macy Conferences on cybernetics from 1946 to 1953 and the research in the following two decades. Early cyberneticians such as Wiener and von Neumann focused on the feedback mechanism and control strategies in homeostatic systems. Towards the end of the first wave of research, anthropologists and philosophers including Margret Mead, Gregory Bateson, and Heinz von Foerster problematized the role of engineers as observers in the model-making process, trying to propose a new framework,
框架——这一框架将观察者作为反馈系统的一部分（图1）。这种观念上的转变引发了20世纪60年代后期至70年代的第二次研究思潮。这期间，学者们致力于探寻观察者在建模过程中的作用，其中智利生物学家温贝托·曼图拉那和弗朗西斯科·瓦雷拉提出了“自生系统论”，以阐释系统如何利用物质和信息流维持自身属性[9]。之后，瓦雷拉开始涉足人工生命领域，并引发了于20世纪90年代初期兴起的第三次控制论思潮，其中的焦点议题是演生论与复杂性。通过人工生命实验这种多智能体模拟，学者们认为诸如“智能”和“意识”之类的复杂现象实际上可以被理解为分布式系统之间相互作用的结果。自20世纪90年代后期以来，第三次思潮开始不断挑战人类例外论，并引发了一系列后人类主义的思考[8]。

控制论的三次思潮的研究焦点可以与景观研究和实践进行比照（图2）。麦克哈格的生态学设计方法对于景观的控制可以视为一阶控制论的一种体现。工程师们通常通过控制熵来维持一个机械系统的稳定性：在热力学中，熵是指系统向着无序状态发展的趋势。麦克哈格在其著作中大量使用熵的概念，并将其与生态适应性进行类比。在他看来，熵即不确定性，会对生态系统的完整性造成威胁。因此，他认为景观设计师应该遵循理想的生态演替模型来控制景观变化，最终达到生态系统“演替顶级”的平衡状态[7]。然而，当代景观理论和实践注重开放性与演生，而麦克哈格设计框架中的环境决定论和对于生态过程的线性理解已遭到质疑[10]。

控制论的第二次思潮可以与大都会建筑事务所（OMA）的两个景观设计项目进行比照。其中一个OMA于1982年参加的法国拉维莱特公园设计竞赛作品，另一个是于20世纪90年代末参加的加拿大当斯公园设计竞赛作品，其中一个是OMA于1982年参加的法国拉维莱特公园设计竞赛作品，另一个是OMA于1982年参加的法国拉维莱特公园设计竞赛作品。这些项目可以被理解为“演替顶级”的平衡状态[7]。然而，当代景观理论和实践注重开放性与演生，而麦克哈格设计框架中的环境决定论和对于生态过程的线性理解已遭到质疑[8]。}

A body of landscape research and projects can be contrasted with the three waves of cybernetics in terms of their major concerns (Fig. 2). McHarg's ecologically inspired design methodology can be understood as a version of landscape control through first-order cybernetics. To control a mechanical system, engineers usually manage the entropy to maintain the system's homeostasis. In thermodynamics, entropy refers to the tendency of a system to move into disorder and chaos. McHarg used the concept of entropy extensively throughout his writing and always compared entropy with ecological fitness. For McHarg, entropy is another term for uncertainty, which poses a threat to the integrity of the ecosystem. Thus, landscape designers’ work is to control landscape change by following a set of ideal models of ecological successions and finally reach an equilibrium state as expressed in the “climax stage” of an ecosystem[7]. From a perspective of contemporary landscape theories and practices that focus on open-endedness and emergence, McHarg’s design framework has been critiqued for its inherent environmental determinism and linear understanding of ecological processes.[10]

The second wave of cybernetics can be contrasted with two landscape projects by OMA. The first one is the entry for the Parc de la Villette competition in 1982, and the second is the entry for Toronto’s Downsview Park competition in the late 1990s called “Tree City”[11][12]. The two projects can be understood as a seriation in which the designers deployed the tactic of “self-production” of the park system as design strategies, and the urban parks were understood as an autopoietic (self-producing) system that uses flows of material and information to reproduce their own organizations. An autopoietic system
维尓公园设计竞赛作品“树城”[11][12]。这两个方案可被看作一个系列，它们都利用“自生系统”作为设计策略，将公园理解为一个自组织系统，即利用物质和信息不断复制自己的体系。所谓自生系统，是指系统通过其内部组织关系来处理信息物质流，从而维持自身特性。例如，在当斯维尔公园竞赛中，OMA用1,000条道路构成的路网和植物簇群作为空间框架，分割出大片未进行功能限定的区域，以满足公园未来发展需求。乍看之下，OMA的“树城”表现出一定的不确定性，因此是开放的。但是，这种灵活性是基于城市公园系统的自我生产，从而维持了另一个层面上的稳态，这种对稳态的控制可以由二阶控制论[13]解释。

景观设计师、理论家克里斯蒂娜·希尔对OMA的设计持强烈怀疑态度，她指出，尽管OMA的文案中描述了一个高度灵活的设计框架，但这个设计本质上还是一个传统的田园牧歌式的城市公园[14]。换句话说，场地通过系统运转来维持其作为“田园式公园”的系统组织，几乎没有为景观演生和未知的发展可能预留任何空间。

由詹姆斯·科纳事务所、斯坦·艾伦与生态学家尼娜-玛丽·利斯特合作的参赛作品“生态演生”可以和控制论的第三次思潮进行比较。第三次思潮注重开放性和演生，而该设计方案的框架将使场地通过人工生命模拟[15]来维持其国家身份，即通过处理信息和物质流来维持自己的体系。例如，在奥尔·麦卡利和弗朗西斯科·瓦雷拉的作品中，作者认为控制论因此是开放的。然而，这种灵活性是基于城市公园系统的自我生产，从而维持了另一个层面上的稳态，这种对稳态的控制可以由二阶控制论解释。
the third wave of cybernetics which focuses on open-endedness and emergence. The team also proposed a framework that allows for a long-term generation of the park based on emergent ecologies. Unlike other finalists which used phasing programs to build an urban park as an end point, Emergent Ecologies considered the initial 15-year phasing program as a strategy to cultivate the long-term potential of the site, providing multiple possibilities of how the site could be used after its construction. In other words, constructing a conceivable and stable urban park was not the goal of this proposal; instead, the aim was to prepare the Downsview site into a territory with a wide range of possibilities. The proposal leaves plenty of space to imagine a place that is wild and vibrant and is fundamentally different from a pastoral urban park.

3 Cybernetic Creatures and Designers’ Simulation

In the framework of emergence and open-endedness, prototypes act as an important component to help exploit the potential embedded in the uncertainty. Since a prototype can be understood as a special family of models, which should be situated in the history of cybernetics movement and analyze how it was conceptualized at large in systems thinking. In a way, prototypes have always existed in cybernetics movement, but the habitual means-end reasoning has limited their “usefulness.” By analyzing a range of cybernetic creatures within the emergence
3.1 The Moth or the Bedbug, Cellular Automaton, and Artificial Life

Early cyberneticians built cybernetic machines and simulations as a way to test out their theoretical considerations. An important artifact was Wiener’s cybernetic machine known as “the moth” or “the bedbug.” In *The Human Use of Human Beings*, Wiener discussed in detail the process of making this “cybernetic robot” to build a working model of the interaction of two kinds of feedback mechanisms in the human nervous system: postural feedback and voluntary feedback (goal-seeking feedback).[19]

Wiener asserted that these two types of feedback mechanisms exist in human behavior and nervous system disorders, and Parkinsonism and intention tremors are the cases when these feedback mechanisms are overloaded and broken down. Wiener further posited that in Parkinsonism, voluntary feedback regulates postural feedback: the tremor happens when the patients are in rest, and when the patients perform a task (goal-seeking), the tremor subsides or even disappears. Wiener expected to conceptualize these theoretical explanations in action by building an apparatus that could act based on the two kinds of feedback mechanisms.

Wiener and his colleagues built a machine called “the moth” or “the bedbug.” It was a three-wheeled cart with two major modes of action, positively photo-tropic (the moth) and negatively photo-tropic (the bedbug). This machine has two types of feedback mechanisms with one regulating the other. For example, to achieve the “the moth” function, the cart carries two photo-cells in the front, and when there is light, the motor will turn the wheel towards the direction of the light. This action will trigger a negative feedback circuit that turns the front wheel in the opposite direction. So, the cart will move towards the light in an oscillating pattern (voluntary feedback). If there is no light, the cart will keep oscillating because there is secondary feedback between the potentiometer and the motors (postural feedback). Moreover, when this feedback is overloaded by adjusting the amplifier in the circuit, the oscillation would grow bigger. This machine was argued to be an analog to Parkinsonism, in which the voluntary feedback suppresses the postural feedback (Fig. 3).[17]

“The moth” can be understood as a physical diagram of feedback mechanism, which was a key concept explored in the first wave of cybernetic research in the Macy Conferences era. However, its “usefulness” cannot be conceptualized within the means-end equation because when the cyberneticians built it, they did not have a specific goal in mind, such as solving a...
Thus “the moth” is not a means to an end. Cyberneticians were simply interested to see the cybernetic principles in action. In the framework of emergence, “the moth” can be understood as a prototype, whose value lies in its uncertainty. Because it functions as an abstracted diagram of feedback mechanism, it can be interpreted differently among different fields, and the proliferation of meaning is the basis of creativity and design. It became a kind of boundary-object that facilitated the thinking and communication of cybernetic principles between scholars from different fields and played a critical role in popularizing the cybernetic principles in its early stage.

The other two examples—von Neumann’s cellular automaton and artificial life experiment—can be discussed as a seriation. The cellular automaton was designed to provide insight into the logical requirements for self-replicating machines. It can be understood as a 2D grid, and each cell presents a finite-state automaton or machine, which can be in one of a finite number of states at any given time. Cells can transmit input to its adjacent cells. In von Neumann’s model, each cell has 29 different states, which can be understood as rules for transition signals. For example, if a cell is in the sensitized state for three cycles, and it receives an input from an adjacent cell, it will enter a transmission state that will pass the data to the cell to its north. There are also rules for transmission state. For example, when an input is given to a cell that is in the ground state (an empty cell), the cell will enter the sensitized state; if somehow two cells...
transmit data to each other, then data disappear. Other rules guide how each cell interacts with its neighbors.

The artificial life experiment is a more complex version of the cellular automaton. Inspired by autopoiesis theory, biologists wanted to explore the implication of second-order cybernetics and how self-production systems can spin off and evolve towards new directions. One famous experiment is called Tierra—A computer program designed to replicate and mutate based on simple rules. The self-replicating program would randomly flip ones and zeros on the computer memory when copying the data. If the new data happened to be machine code for another program, the original program mutated. A “reaper” function would “kill” old or defective programs when the computer memory became full. By repeating this simple process, a computer program could evolve into different “ecosystems” with a wide range of digital species.

The artificial life experiment had a high value in the discourse of posthumanism because it showed that complex behaviors, such as human thinking, were epiphenomenon of interactions between distributed systems, such as neural networks, and this realization allowed posthuman proponents, such as Hayles, to challenge human exceptionalism.

These feedback biological examples have no clear definition, and are flexible and undetermined, which makes them prototypes, different from contemporary environmental practices such as adaptive management. A predictive model entails a model-environment difference, as the model has a metaphorical quality, and it represents a phenomenon in reality. With predictive models, the gap between the model and the environment is conceptualized as uncertainty that can only be conceptualized as negative forces undermining control regimes. Nevertheless, a prototype has a twofold quality. On the one hand, like predictive models, a prototype has metaphorical quality, that is, it uses one thing to refer to another thing; “the moth” is a working diagram of feedback mechanisms. On the other hand, it has a sense of realism in it because it exists as part of reality so that other artifacts can be said to be derived from it. This twofold quality makes prototypes a special type of model that does not predict or determine, but inspire and anticipate.

3.2 A Case Study: Hydromorphology Table

In the scientific and engineering practice of physical hydraulic modeling, large physical river models are built to simulate weather and flood events and to evaluate the effect of flood control strategies. Precedents include large-scale hydraulic models built in the 1950s by the Army Corps of Engineers such as the Mississippi Basin Model and the San Francisco Bay Model. On the other spectrum, digital models and simulations are also widely used...
in environmental practices to predict system behaviors and evaluate control strategies, such as the South Florida Water Management Model\textsuperscript{22}. These models, physical or digital, are all envisaged in the line with means-end relationships for prediction and control. The models begin as an ideal representation of the environment so that they can be projected and used to give form to reality. However, as pointed out by Jullien, following this line of reasoning, there will always be unexpected circumstances outside the scope of predictions that are allowed by the models. Thus, one is constantly challenged by the tension between control and uncertainty. Development in digital tools and computational methods has provided landscape architects with advanced techniques to build prototypes that challenge the predictive models and means-end reasoning. To better illustrate how prototyping helps with design thinking, this paper presents a series of case studies based on a hydromorphology table to demonstrate the qualities of prototypes and the value of prototyping.

The hydromorphology table was based on the Emriver stream table and was located at the REAL in Harvard GSD\textsuperscript{2}. The Emriver stream tables, which were usually used by hydrologists, were introduced to the field of Landscape Architecture as a prototyping platform to help designers better understand hydro-morphological processes, and to facilitate the production of responsive design strategies. The inputs of both the sediments and water flow were controlled through 4 material feeders and a water pump to simulate water flows and behaviors of sediment. The table allowed for running iterations of the same hydromorphological system with measurable adjustments, as well as testing multiple systems with the same flow and sediment input. Besides the instruments provided by the Emriver, the prototype platform was also equipped with sensing and monitoring devices to gather real-time data, including a Microsoft Kinect above the table and ultrasonic sensors down the stream. The real-time data then were fed into Rhinoceros 3D through grasshopper plugins and customized interfaces.

As a prototyping platform, the hydromorphology table facilitates many research and design projects over the years, shedding light on the possibility of constructing autonomous systems that can devise strategies beyond human comprehension to create “wild” places\textsuperscript{23}. For instance, designer Leif Estrada tested the sensing-processing-actuating responsive framework in the project Towards Sentience\textsuperscript{24}. In one of the design experiments, the designer proposed an actuating system called “attuner” that consists of a matrix of acrylic dowels connected to servo motors. Every servo motor drives a dowel, the bottom of which sticks into the sediments. When the servo motors...
器” 的系统，该系统由连接到伺服马达的一组亚克力杆组成。每个亚克力杆均由伺服马达单独驱动，其底部插入沉积物中。当伺服马达转动时，会驱动亚克力杆上下移动来改变水流形态，从而在沙床的下游形成不同的地形。随后，通过沙床上方的Kinect传感器实时跟踪地形，形成数字高程模型，以识别出地势的高低。这些信息会反馈到制动系统，这样就能在高地上借由更多的沉积物来造陆，或引流更多的水体来侵蚀陆地。埃斯特拉达描述道，水文地貌模拟沙床构建的控制系统具有实时更新和反馈能力，而这种自主能力是人类无法企及的[25]。

在另一个示例中，设计师刘浔基于实体界面（TUI）的概念开发了一种混合仿真模型[26]。TUI逐渐取代了传统的图形用户界面（GUI），它结合了物理模型和数字模型的优势，现已被广泛用于增强物理模型性能以及物理模型的数据可视化，从而实现“比特和原子”的无缝耦合[27]。自定义程序使用从Kinect传感器感测到的高程数据来生成实时数字地形模型，该模型可在Rhino和其他软件中用于进行水流、植被分布、污染物和沉积物等不同类型的数值模拟（图4）。地形变化、景观

4. Customized digital hydrological simulation and visualization tool
形态、水流线，以及其他模拟图像都可通过短程投影仪投射到沙床上（图5）。如此，基本的地形分析与动态流体模拟被集成到同一个平台中，可以更好地实现地形数据的可视化，数字模拟和物理模拟也能通过反馈回路实现耦合。设计师可以依据沙床上的投影信息（如等高线和填方图）即时手动调整物理模型（图6-9）。

增强现实的沙床可成为景观设计师新的设计工具，也可被当作一种合作平台，帮助社区参与中的不同利益相关者进行沟通协商。该原型并非基于设计构思到计算机模拟，再到材料处理与结果呈现的线性设计过程，而是开启了一种新的工作流程，其支持设计过程中的不同步骤同时或反复进行。本实验中讨论的实体交互概念超越了界面的接触，是指两种不同类型的模拟的协同与组合：数字模拟可用于验证物理模拟，物理模拟可用于检测数字模拟，两种模拟相互配合并彼此适应。通过运用增强现实技术将物理河流模拟与实时的数字河流模拟相整合，该原型便使景观设计师可以直观地利用有形的材料进行设计，并同步获得计算机模拟结果的校验。作为设计师与实体空间之间的动态界面，实体交互模型的变化性和不确定性对于理解水力形态过程的复杂性和动态过程非常重要。

需要特别指出的是，沙床模型并没有按照真实景观比例来建造，所以该原型不宜用来模拟特定地点的水文和生态系统。换句话说，如果以手段-目的链来理解沙床的概念，那么沙床必须按照真实环境的比例来建造，这样才能用于预测设计结果并决定相应策略（如密西西比河流域模型或南佛罗里达水管理模型）。但是，围绕模型制作的讨论最终离不开如何用模型“精确”地表达环境的问题，这与模型参数的不确定性有关。在建模中，造成不确定性的原因有很多，如结构的不确定性、算法的不确定性等。其中，参数的不确定性来自模型输入变量的可变性。对于沙床而言，设计人员可以通过调整介质的大小以及不同介质之间的比例改变河道“沉积物”的组成，进而调节水流的速度和流量。这些是模型本身包含的变量，更改其中的任何变量都将对模拟结果产生显著影响。如果将沙床视为一个预测性模型，那么设计人员需要计算建模过程中的所有参数值，以最大程度地减少参数的不确定性。设计人员不仅必须选择合适的材料尺寸来模拟真实的景观环境，而且需要确定恰当的材料构成比例，更不用说计算流程中涉及的物理变化。因为理论上除了水以外，所有事物都变小了。为了解决这个问题，设计人员必须找到另一种具有适当粘滞阻力的流体，以代表流体与要按比例缩放的固体颗粒之间的相互作用。由此可知，如果遵循手段-目的链来理解沙床，会不可避免地将它看作一种重构现实世界的理想模型，而这种想法会导致不确定性永远存在。最重要的是，这种基于手段-目的链框架visualized in diagrammatic representations. These representations then can be projected back onto the hydromorphology table with a short-throw projector (Fig. 5). In such a way, basic terrain analysis is integrated into this platform together with dynamic fluid simulation to better visualize the invisible aspects of the topography, and the digital simulation and the physical simulation are coupled through a feedback loop. Designers can manually change the physical model according to the projected information, such as contour lines and cut-and-fill maps (Fig. 6-9).

This augmented hydromorphology modeling table can be used as a new design tool for landscape designers, as well as a cooperation platform for community engagement and communication between different stakeholders. Rather than developing design in a linear progression from idea to computersimulated model, and material manipulation and result, this prototype inspires an alternative workflow that allows different steps in the design process to play concurrently or recursively. The concept of tangibility developed in this experiment is more than the tangibility of the interface, but the synthesis and composition of the two different types of simulation: numerical models being used to manipulate while validating physical models, and vice versa. Two kinds of simulations feed and adapt to each other. By integrating physical hydraulic simulation with the real-time computational fluvial simulation through augmented reality technologies, this prototype allows landscape architects to design intuitively with tangible material processes and simultaneously be
informed by computational simulation results. The dynamics
and indeterminacy of the tangible model are important in
terms of understanding the complexity and dynamic process
of the hydro-morphological process. This prototype acts as a
dynamic interface between designers and the physical world.

Particularly, this hydromorphology table as a prototype is
not meant to replicate processes in a site-specific hydrological
and ecological system. The presumed scale of the model is
not built based on a mathematically scaled relationship with
real landscape conditions. In other words, if the table is
understood in the means-end relation, it can only exist as a
scaled simulation of the real environment so that to predict
and determine outcomes of different intervention strategies,
like the Mississippi Basin Model or the South Florida Water
Management Model. However, the discussion about model-
making would eventually revolve around the question of how
“accurate” the model is to represent the environment; that
is, the parameter uncertainty involved in the simulation. In
modeling practices, uncertainties come from various sources
such as structural uncertainty and algorithmic uncertainty.
Parameter uncertainty comes from the variability of input
variables of the model. In the case of the hydromorphology
table, the designer can change the composition of the
“sediment” by adjusting the size of each material and the
percentage of that material in the sediment mixture. The
designer can also vary the flow of water in terms of speed
and quantity. These are all implicit variables involved in the
model itself, and changing any of them could easily alter the
outcome of the simulation. If the table is treated as a predictive
model, then the designer is challenged to minimize parameter
uncertainties by figuring out the values of all the parameters in
the modeling process. The designer has to select not only the
correct size of the material to emulate the sediment on-site but
also the composition of the material that best represents the
sediment. Not to mention that the designer has to calculate the
underlying physics involved in the scaling process itself, since
everything but water is scaled down; and to counter this issue,
the designer might have to switch to another type of fluid with
the right viscosity that best represents the interaction between
the fluid and the solid particles to scale. These examples only
provide a glimpse of the line of reasoning that one inevitably
takes if one follows the means-end equation and understands
the hydromorphology table as a model of an ideal form to
reconstruct the reality. In such conceptualization, uncertainty
always exists. Most importantly, following the means-
end equation, the discussion drifted away from the design
practice and creativity. However, if designers understand the
控制论运动和景观设计的进步揭示了自20世纪60年代以来的现代景观设计发展历程概括着控制论的三次思潮。不确定性概念最初被理解为模型与环境间必须要被消除的差异，即后来被理解为演化与机遇的来源。在演化论的框架下，原型被解读为一种特殊的模型。将其与预测性模型进行对比，会发现二者对不确定性有着截然不同的理解思路。利用预测性模型思考问题，会不由自主地通过手段-目的链来理解不确定性，环境也因此被简化成一种理想化模型，任何的行为都必须具有目的性，必须通过手段来实现一个最终目标。不同与预测性远景所追求的生命系统，原型本身就是一个独立自主的生命系统，不存在与现实环境的差异，因为原型正是环境的一部分。用原型思维取代模型思维后，不确定性也有了新的含义——更多的机会与期待。在原型思维模式中，不确定性将激发演化行为，以及无限的可能性（图10）。

4 Conclusion and Discussion

Contrasting the cybernetics movement with landscape design reveals that the development in landscape discourse since the 1960s mirrors the movement of cybernetics. Uncertainty has transformed from the early understanding that the disconnection between the model and the environment has to be reduced to a contemporary understanding that uncertainty can be the source of emergence and opportunity. The framework of emergence highlights prototypes as a special type of model. Prototypes can be contrasted with predictive models as they entail two different lines of reasoning around the issue of uncertainty. With predictive models, we are forced to understand uncertainty within a means-end relationship that reduces the environment to a simplified representation or ideal image, and then make it a goal and an end, which calls for means to achieve it. Rather than predictive models that represent another living system, prototypes are living systems in themselves with autonomy and lives, and no longer entail a model-environment difference because they are part of the environment. Prototyping replaces model-making and helps establish a new relationship with uncertainty in the line of opportunity and anticipation. Uncertainty in the paradigm of prototyping can be understood as the source for emergent behaviors and a wide range of possibilities (Fig. 10).

There are three characteristics of the paradigm of prototyping. First, prototypes might start as a test of a principle or an idea, but when they are built, they take on a life of their own and become part of reality that triggers new rounds of observation and model-making. This iterative process is the basis for design and creativity. Second, prototypes may have some direct applications, but their true application lies in their undefined identity. “The moth” did not even have a proper name, and neither did the hydromorphology table. However, just because of this undefined identity, a prototype has the potential to become anything. Third, because of this undefined quality of prototypes, they are full of uncertainty, thus infinite possibility, and our relationship with the future has changed. LAF
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