建筑·运算·应用
教学与研究 I

Architecture · Algorithms · Applications
Education and Research I

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中国建筑工业出版社

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东南大学建筑学院的前身是中央大学、南京工学院和东南大学建筑系。2003 年，在原建筑系的基础上组建"建筑学院"。其是中国大学建筑教育中最早的一例，自 1927 年建系以来已走过 90 年历程。90 年筚路蓝缕、成长壮大、传承创新，为国家培养了包括院士、大师、总师、院长等在内的大批杰出人才，贡献了大量重要的学术成果和设计创作成果，成为中国一流的建筑类人才培养、科学研究和设计创作的基地，并在国际建筑类学科具有重要影响力。值此 90 周年院庆之际，编辑出版《东南大学建筑学院 90 周年院庆系列丛书》，一为温故 90 年奋斗历程，缅怀前辈建业之伟；二为重温师生情怀和同窗之谊，并向历届师生校友汇报学院发展状况；三为答谢社会各界长期以来对东南大学建筑学院的关爱和支持。

这套丛书包括《东南大学建筑学院学科发展史料汇编 1927-2017》、《东南大学建筑学院教师访谈录》、《东南大学建筑学院教师设计作品选 1997-2017》、《东南大学建筑学院教师遗产保护作品选 1927-2017》、《绿色建筑设计教程》、《建筑·运算·应用：教学与研究 I》等共计 6 册。其中《东南大学建筑学院学科发展史料汇编 1927-2017》完整展现了东南大学建筑学院各学科自 1927 年建系至今的发展历程，整理收录期间的部分档案资料，本书亦可作为研究中国近现代建筑教育源流及发展的参考资料；《东南大学建筑学院教师访谈录》收录了部分老教师的访谈文稿，是学院发展各阶段的参与者和见证者对东南建筑学派 90 年发展历程生动且真切的记录和展现；《东南大学建筑学院教师设计作品选 1997-2017》汇集了近二十年来建筑学院在任教师的规划设计作品共计 99 项，集中反映了东南大学教师实践创作的成果、价值与贡献；《东南大学建筑学院教师遗产保护作品选 1927-2017》依实践中涉及的建筑遗产保护五大类型，选有自 20 世纪 20 年代以来 90 余年完成的保护项目共 65 例；《绿色建筑设计教程》是近年来学院在建筑学前沿方向教改

研究的成果之一，体现了在面对全球气候变化和能源环境危机时建筑学教育的思考与行动；《建筑·运算·应用：教学与研究I》着眼于计算机编程算法，在生成设计、数控建造和物理互动设计等方向，定义、协调或构建与城市设计、建筑设计、建造体系相关的各种技术探索，结合教学激发多样设计潜能。

期待这套丛书能成为与诸位方家分享经验的桥梁，也是激励在校师生不忘初心，继续努力前行的新起点。

编者识

序

东南大学建筑学院数字技术教学与科学研究起步于20世纪80年代，卫兆骥教授为此作出了开拓性贡献。1990年，国家教育部批准东南大学"CAAD实验室"计算机辅助建筑设计实验室为国家重点专业实验室。2000年，联合国教科文组织在此设立"亚太地区技术网络服务中国中心"。2005年起，相继开始探索生成设计等新技术及教学实验。2010年，建筑学院设立"建筑运算与应用实验室"。2015年，正式成立"建筑运算与应用研究所"，由李飚教授出任所长。经过三十余年的探索与发展，这一新兴的学科领域已超越传统的设计思维方法和一般性数字化工具的运用，在生成设计、数控建造和物理计算等方面取得了可喜成绩。此三大方向着眼于利用计算机编程算法，定义、协调或构建与城市设计、建筑设计、建造体系相关的各种技术探索，进而通过特定的算法技术，激发多样的设计创新潜能。

众所周知，数字技术正以前所未有的速度与建筑学科融合。建筑数字技术的迅猛发展极大地拓展了人们对建筑及其环境的认知方式及其相应的设计方法，对建筑的建造和相关产业产生了极大的影响，同时也对建筑教育提出了新的命题。数字建筑同样将建筑视为一种建造的技艺，并形成相应的建构文化。数字建筑的研究和实践具有鲜明的多学科联合交互的特性，它不仅涉及建筑学、计算机科学和电子信息科学自身的诸多问题，还涉及人文、经济、地理、气候、能源以及结构、材料、建造等多个领域的知识范围。这种跨学科的教学和研究不仅能帮助我们拓展视野，加强各相关学科之间的合作和交流，也促使我们重新思考和探索建筑学如何与各种新技术相融合以便产生更适应于人们需要的设计和更具可持续性的设计。可以说，运算已经成为推动建筑学学科创新的不可或缺的思维力量和技术要素。

2016年，建筑运算与应用研究所主办以"建筑·运算·应用（Architecture·Algorithms & Applications）"为主题的国际会议和展览，意在对过去6年来的相关研究和教学实验进行总结，并邀约国内外该领域的部分专家学者展开探讨。这次活动引起与会学者的积极反响，并受到观展者热烈赞誉。本书收录了此次参展作品的主要内容，是对近年来建筑运算与应用研究所探索之路及其成果的客观记录。我认为，坚持严谨务实的学术作风，坚持以学科问题和社会需求为目标引领，坚持开放引进与自主探索的有机结合，

坚持在学科交叉互动中实现技术创新，坚持人才培养与科学研究的融合发展，这是运算所在较短的历程中取得教学和研究突破性进展的基本信念基础。

建筑运算与应用研究所是学院最年轻的研究机构之一，拥有一支风华正茂、充满朝气的学术队伍。"回眸"显然不是当下的趣意，"展望"才更加吻合数字技术的本旨。与其他新型工程学科相比，建筑学科更需要充分意识到新需求和新技术的挑战，这也正是其创新发展的新机遇。建筑学科故有的人文创意属性则从另一个侧面提示了其数字技术发展的独特目标与路径。因此，我们亟需与相关学科和工程领域互联合作，以全新而专业的视角去学习和解读相关的学科知识、方法及其背后的思维特征。从这个视角看，生成设计、数控建造、物理计算可能是极具发展价值且需要深入拓展的跨学科研究领域，也是未来一个时期建筑运算与应用研究所的学术团队可以大展拳脚的领域。

东南大学建筑学院院长　韩冬青

2017 年 5 月 23 日于中大院

PREFACE

It was from the 1980s that School of Architecture Southeast University start the scientific research of digital technology with Prof. Wei Zhaoji's ground-breaking contribution. In 1990, the Ministry of Education approved the university's "CAAD Laboratory" for the National Key Professional Laboratory. In 2000, UNESCO established the "Asia-Pacific Regional Network for Technical Services China center" here. New technologies and teaching experiments such as generative design have been explored since 2005. In 2010, the School of Architecture set up "Laboratory of Architectural Algorithms & Applications" and the formal "Institute of Architectural Algorithms & Applications" (Inst. AAA) was established in 2015 with Prof. Li Biao as director. After more than 30 years of exploration and development, this emerging subject has gone beyond traditional design thinking methods and general digital tools with gratifying achievements being made in the generative design, digital fabrication and physical computing. These three directions focus on the use of computer programming algorithms for defining, coordinating and constructing various technical explorations related to urban design, architectural design and fabrication system, and then through specific algorithmic technologies to stimulate all kinds of design innovations.

It is well known that digital technology is being integrated with the field of architecture at an unprecedented speed. The rapid development of digital technology in architecture has greatly expanded the human consciousness about architecture and its environment as well as the corresponding design method, and greatly influenced the building construction and related industry. Meanwhile, it has also proposed new topics to architectural education. Digital architecture also considers architecture as a kind of construction method and eventually evolves to tectonic culture. The research and practice of digital architecture has a distinct characteristic of multidisciplinary integration. It not only involves issues of architecture, computer science and informatics, but also knowledges in respect of humanity, geography, energy, structure, material, construction and so on. Such interdisciplinary teaching and research can not only help us expand our vision and intensify the cooperation and communication among disciplines, but also

promote us to re-consider and explore how architecture can get integrated with various new technologies so as to bring about more functional and sustainable designs. That is to say, computation has become an indispensable thinking and technical element to promote the innovation of architecture.

In 2016, Inst. AAA hosted an international conference and exhibition on the theme of "Architecture, Algorithms, Applications", which was intended to summarize the relevant research and teaching experiments over the past six years. Many experts and scholars in this field were invited from home and abroad. The exhibition aroused participants' positive responses and was warmly praised by audiences. This book contains the main contents of the exhibition works, which are the exploration and achievements of Inst. AAA in recent years. I believe adhering to the rigorous and pragmatic academic environment and leading by the academic and social function, combining open invitation and independent exploration, realizing technology innovation from interdisciplinary interaction and integrating personnel training and scientific research are the bases for Inst. AAA to get teaching and research breakthroughs in the past short time.

The Inst. AAA has a vibrant academic team, which makes it one of the youngest research institutes in our school. "Looking back" is clearly not its interest for the moment, "Looking out" is more consistent with the purpose of digital technology. Compared with other emerging engineering disciplines, the field of architecture needs to be fully aware of the challenges from new demands and technologies, which are also new opportunities for innovation and development. The humanistic creative attributes of architecture suggest the unique goals and path of the development of digital technology. Therefore, we need to cooperate with related disciplines and engineering fields with a new and professional perspective to learn and interpret knowledge, methodologies and thinking behind. From this view, the generative design, digital fabrication and physical computing might be highly valuable interdisciplinary research fields that need further exploration and future work from Inst. AAA.

Dean of School of Architecture, SEU
Prof. Dr. Han Dongqing
In Zhong DaYuan   May 23rd, 2017

　　长期以来，建筑设计被置于理论和实践两面平行的镜子之间，相同的问题被无限复制，共同的原型被迭代递归，在"设计黑箱"的裹挟下数理运算缺乏直接展示其强大功能的机会。在过去的 20 年中，数字技术与建筑学学科迅速融合，其设计思想、设计方法、设计过程、建造流程、项目管理等方面都朝着更科学而系统的方向发展。复杂系统、人工智能与建筑数字技术相互嫁接逐步催生出以建筑生成设计、数控建造、互动设计等为代表的建筑学学科分支。一方面，建筑师对数字技术的解读不断变更，技术投入在实践与科研中获得了丰厚的回报，建筑数字技术正为建筑学学科充实崭新的理论与方法；另一方面，建筑数字技术本身也急需奠定系统的探索基础，数学与算法技术比以往任何时候都更符合建筑学的要求，并期待建立智能且包含众多接口的可扩展架构。

　　运算已经解决了科学领域的众多问题，但建筑运算的计算方法与它们大相径庭，其计算范式也不能被粗暴移植，寻求建筑晦涩定义的理性策略正成为学科共同的探索目标。对于建筑学的特定问题可以采取多种技术实现，但那些面向系统与框架的算法构建明显优于简单工具的等效替代。算法设计被确定并融入建筑数字技术研究，旨在寻求并获得算法设计的计算模式。特定的演化算法具有并行、进化和自适应特征，并将多种学科要素分解成直观的算法描述，甄别功能性因素与艺术性特征；以抽象的方式来获取最终产品的直接代理，进而提供全局优化的自适应解决策略，必将广泛应用于建筑学学科的模型建立。

　　与建筑数字技术相关的另一个重要角色是"创意代理人"：以数控设备为代表的机器工匠们。它们直接接触建筑材料，并在加入之初便以高效和精确为目标发挥其独特专长。在这个新奇的转置过程中，合理的空间与时尚的形式已经满足不了建筑师和业主的胃口，加工技术为建造提供了工厂组装模式，"数字链"系统一方面可以展示规则、非规则复杂要素的变化规则，另一方面它们仍包含成果与预定义的逻辑关联，同时祈求成果的多样性与个性化并存。

　　基于数字技术的设计方法为建筑设计提供了令人兴奋的机遇，它们并非传统设计方法的替代品，而是其有益的延伸。大数据的分析与提取正逐步形成统计分析和数据挖

掘的数理与逻辑同构，并为建筑学学科提供科学的动态演化机制，形成彼此促进、互为依存的学科共生。建筑学学科已经到了一个拐点，算法与制造技术的成熟意味着建筑学正在进入一个前所未有的飞速发展时期，建筑数字技术的递归出口已经形成，各类匪夷所思正在变成现实，并呈现出目不暇接的视觉冲击和模式矩阵。

李飚

2017. 10.

For a long time, architectural design has been placed between parallel mirrors of theory and practice, which replicates the same questions infinitely and iterates universal prototypes recursively. Dissembled by the "black box" of design, the rational mathematical approach lacks opportunity to show its powerful function. During the past 20 years, owing to the rapid integration of digital technology and architectural discipline, its design methodology, construction process, project management and many other aspects are moving towards a more scientific and systematic direction. Complex system, artificial intelligence and architectural digital technology graft each other and help to emerge research branches of generative design, digital fabrication and interactive design. On the one hand, the architect's interpretation of digital technology is changing, and the technological investment obtains a lucrative return in practice and research. Digital technology is enriching architecture with new theory and methodology. On the other hand, architectural digital technology itself needs system-laying foundation for exploration. Mathematics and algorithm technologies are fitting the requirements for architecture more than ever and anticipating the establishment of intelligent and multi-plugin expandable structure.

Algorithms have solved many problems in science, but the methods of algorithm employed in architecture are very different and the calculation paradigms cannot be brutally transplanted. The rational strategies for seeking obscure architectural definitions are becoming common exploration targets. Specific architectural problems can be solved by a variety of techniques, but those algorithms facing system and framework are significantly advanced than the equivalent substitute of simple tools. The algorithmic design is identified and integrated into the research of architectural digital technology, aiming to obtain the computational model of the algorithmic design. Specific evolutionary algorithm has features of parallel, evolutionary and adaptive, and can decompose various disciplinary elements into intuitive algorithm description that distinguishes between functional reasons and artistic features. By the way of abstracting, it becomes the

direct agents of final product and provides global optimization of the adaptive solution strategies, eventually being widely used in establishing the model for the architecture discipline.

Another important role associated with architectural digital technology is "creative agents": CNC machines, represented by equipment of computer numerical control. They are in direct contact with building materials and are uniquely focused on efficiency and precision from the very beginning. During this novel transition, neither functional space nor fashionable form would satisfy the appetite of architects and clients. Processing technology provides construction with factory assembly mode. "Digital chain" system can show the evolving rules of regular or irregular complex elements and meanwhile still contain the logic relationship between results and pre-definition, anticipating both diversity and personality from the results.

Digital technology-based design methods provide an exciting opportunity for architectural design, which are not a substitute for traditional design methods but rather a powerful extension. The analysis and extraction of big data are gradually forming the mathematical and logical isomorphism of statistical analysis and data mining and by providing scientific dynamic evolution mechanism for the architecture discipline, there forms a symbiosis relationship that is mutually promotive and interdependent to each other. Architecture has reached a turning point, with the maturity of algorithms and manufacturing technology marking that architecture is entering an unprecedented period of rapid development. The architectural digital technology's recursive exits have been formed and all the unbelievable things have become reality, presenting to us constant visual impacts and pattern matrixes.

Li Ruan

2017. 10.

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