

本文引用格式 / Please cite this article as:

He, W. Y. (2019). From Competition, Coexistence to Win-Win — Relationship between Intelligent Design Tools and Human Designers. *Landscape Architecture Frontiers*, 7(2), 76-83. <https://doi.org/10.15302/J-LAF-20190207>

竞争、并存与共赢 ——智能设计工具与人类设计师的关系

FROM COMPETITION, COEXISTENCE TO WIN-WIN — RELATIONSHIP BETWEEN INTELLIGENT DESIGN TOOLS AND HUMAN DESIGNERS

1 智能设计工具的本质特征与演进历程

近年来，人工智能开始介入城市规划和建筑设计等领域，形形色色的“智能化设计工具”随之陆续面世。然而，当前业界对“智能设计工具”这一概念仍缺乏清晰的定义，由此导致人们对这一新事物的认可程度不一，从而影响了设计工具的整体智能化进程。

智能设计工具有别于传统设计工具的一个本质特征在于：前者不仅能根据人类设计师输入的基地信息与各种限制条件生成设计方案，还能依据一定的标准对方案的优劣做出判断——评判标准既可基于客观理性因素，也可融入对主观感知因素的考量，以体现人类设计师的

<https://doi.org/10.15302/J-LAF-20190207> 采访时间 INTERVIEWED DATE / 2019-04-01 中图分类号 / TP294 文献标识码 / B



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摘要

随着智能设计工具在建筑设计、城市规划等领域的应用越发普遍，对其核心本质、存在价值与发展脉络的探讨与梳理也变得越发必要。作者基于自身多年的研究与实践经验指出，智能设计工具的本质特征之一是其能够与人类进行互动（如对人类设计师的方案进行基于复杂标准的判断、优化与反馈）；其重要价值在于解放人类设计师的双手以促进其提升自身核心竞争力，以及打破设计知识与理念传播的壁垒。在具体的规划设计工作中，人类设计师与智能设计工具各有所长，两者应互为补充、共同进步。作为人工智能等新兴科学与传统设计学科相互启发与融合的产物，智能设计工具在未来的应用领域将不断扩展，并推动建筑设计、城市规划和景观设计等学科之间更为密切的合作，在提高设计质量与行业整体效率的同时，促进对设计哲学与深层价值的深入探讨。

关键词

人工智能；建筑设计；工具；深度学习；智能辅助

ABSTRACT

With its increasingly wide application in the fields of architecture and urban planning, intelligent design tools require a review on its essence, core value, and evolution. Based on her several years' experience of research and practice, the author points out that one of the essential characteristics of intelligent design tools is their ability to actively interact with humans (such as the assessment, optimization, and feedback of human designer's schemes). The core value of intelligent design tools lies in that they can liberate human designers from repetitive work and break down the barriers in communicating design knowledge and ideas. Human designers and intelligent design tools both have their own strengths in the real practices; the two should complement each other and make progress together. Being a product of inspiration and integration between emerging sciences, such as artificial intelligence, and traditional design disciplines, intelligent design tools will enjoy an ever-expanding realm of application. It will facilitate cross-disciplinary cooperation in Architecture, Urban Planning, and Landscape Architecture at varied scales, which not only promotes explorations on design philosophy and deep design values, but also help improve design quality and the overall efficiency of the industry.

KEY WORDS

Artificial Intelligence; Architectural Design; Tools; Deep Learning; Intelligent Assistance

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① “小库”是以智能设计（只需通过在线圈地或上传基地CAD文件、输入基本限定条件、选择楼型三步简单操作，再通过“小库AI大脑”进行方案设计及智能推荐）、智能审图（将二维方案变为三维空间模型，排查潜在错误，并输出多项结果）和智能报告（自动输出含基地分析、方案对比、指标呈现等内容的演示文稿）等功能为主的人工智能设计云平台。在引入云端计算与反馈、大数据收集与分析、机器学习与深度学习技术后，小库的运行规则中包含更多如美观性、社会性等相对主观的考量因素，以做出综合效益更高的选择。

① XKool is an AI design cloud platform that supports intelligent design (generating design proposals and intelligent recommendations through XKool AI Brain by inputting site map, defining requirements, and selecting building types), intelligent review (turning a 2D design into a 3D model, troubleshooting potential errors, and outputting multiple results), and intelligent report (automatically outputting a PowerPoint file that includes site analyses, proposal comparison, and indicator presentation). After introducing techniques such as cloud computing and feedback, big data collection and analysis, machine learning and deep learning, XKool integrates more subjective considerations such as aesthetics and sociality into its operation rules, to maximize the overall benefits of the design.

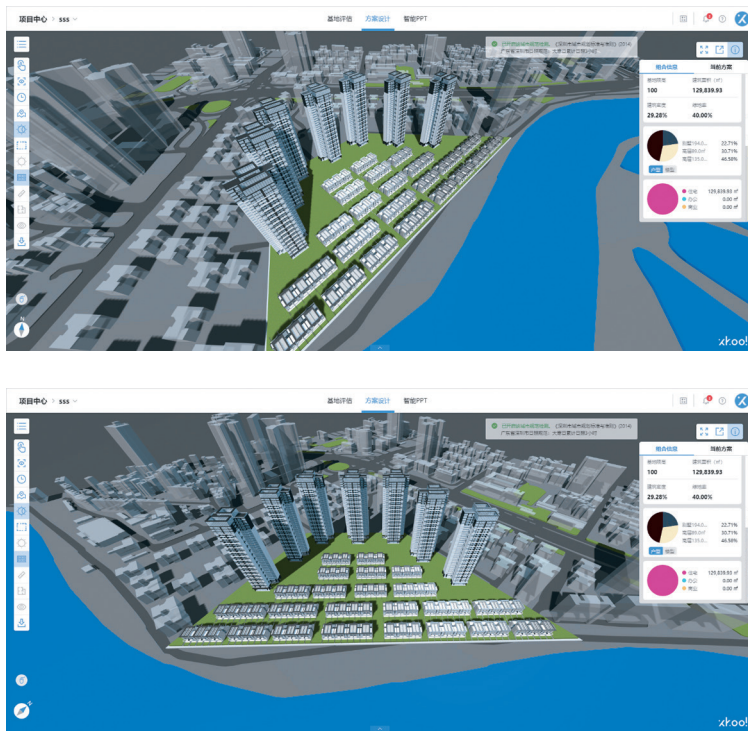
1. “小库”及其智能设计方案展示
1. XKool and a scheme generated through its intelligence design

个性化偏好——并反馈给人类设计师，以辅助后续设计；后者仅能输出结果而不能对结果加以反馈，即只能被动地为人类所用。

上述特征的形成与人工智能技术持续的迭代更新密不可分。早期智能设计工具高度依赖专家系统进行机器学习，通过半自动化方式完成前期规划阶段的大量计算工作，以节约前期设计的时间与人力成本^[1]。就本质而言，其功能仍然止步于“穷举”，而无法为设计师提供更多参考；随后，基于统计学习、特征抽取和优化技术的监督学习算法，以及基于深度学习技术的一系列非监督学习算法的出现，进一步优化了设计工具的运行逻辑，使其功能向寻求近似最优解的方向演进。2017年，AlphaGo ZERO研究成果的正式发表推动了“强化学习”技术在设计工具智能化进程中的应用。该技术可使设计工具摆脱具体案例数据库的限制，直接利用由其学习到的抽象“规则”生成的初始模型进行对抗和迭代，通过不断重复这一过程，最终生成最符合甚至超出人类设计师预期的方案模型，从而真正具备探索未知的创新能力。

“小库”（XKool）^①（图1）即是沿着上述路径进行迭代的典型代表。

智能设计工具的出现，还有助于打破设计学科与行业之间的知识壁垒，促进不同设计理念与设计语言的交流、融合与传承。将深度学习与强化学习算法进一步用于对不同设计案例的风格或表现手法进



1 Essential Characteristics and Evolution of Intelligent Design Tools

In recent years, artificial intelligence (AI) has been more introduced into the fields of urban planning and architecture, with the emergence of all sorts of intelligent design tools. At present, however, professionals' understanding and recognition on the concept of "intelligent design tool" is ambiguous and varies, impacting the overall development of intelligent design tools.

What essentially distinguishes an intelligent design tool from a traditional design tool is that it can not only generate a design based on specific site information input by human designers, but also evaluate the plan according to certain criteria (scientific or individually preferred) and automatically feedback to designers, providing a basis for subsequent design. A traditional design tool, on the other hand, can only be used to generate outputs as what human designers require but not offering feedback.

The nature of intelligent design tools is defined by the continuous technological advance of AI. The early intelligent design tools, relying heavily on expert systems for machine learning, were developed to improve the calculating efficiency in pre-planning stages with semi-automation technology, in order to help reduce time and labor cost on massive calculation^[1]. Essentially, these tools perform to generate all kinds of design possibilities, with no capability to inform designers with a reference. After that, the emergence of supervised learning algorithm based on statistical learning, feature extraction, and optimization techniques, accompanying with a series of unsupervised learning algorithms based on deep learning technology, have further improved the running logic of design tools for exploring an approximate optimal solution. In 2017, the official publication of AlphaGo ZERO showed research results that promoted the application of reinforcement learning technology in developing intelligent design tools. It freed design tools from the limitations of the database of real cases towards a direct use of initial models generated by rules they have learnt in confrontation and iteration. By repeating this process, a model that best meets (or even exceeds) human designers' expectations and has a true potential for exploring the unknown is finally generated. The above path is best manifested by the development of XKool^① (Fig. 1).

The emergence and development of intelligent design tools helps break down the walls among different design disciplines and industries and encourage the exchange, integration, and inheritance of design knowledge, concepts, and languages. Deep learning and reinforcement learning algorithms have been used in case studies on design styles or expression techniques. It is expected to learn and extract a series of design logics and form a new knowledge



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② 小库科技于2017年宣布启动“罗塞塔计划”，旨在打造建筑设计领域的“罗塞塔石碑”，即通过对大量已有的优秀建筑设计案例进行深入学习，建立一个关于设计风格、逻辑与理念等的庞大知识库，并输出学习后的智能设计成果供设计师参考。

② In 2017, XKool launched its Rosetta Project, which aims at creating the "Rosetta Stone" in the field of Architecture. The idea is to build a large database of design styles, logics, and ideas by studying a large number of existing exceptional architectural cases. It is expected to output more valuable intelligent design results to inform human designers.

2. 小库“罗塞塔计划”通过深度学习海量建筑设计案例后，智能“设计”的百万级“现代主义建筑风格素材库”。

2. Based on the deep learning on massive real cases, XKool's Rosetta Project has produces a material library of millions of intelligent Modernistic architecture designs.

行分析与学习，则有望提炼出其内在逻辑，形成设计领域的新知识图谱。由此，正如古埃及的罗塞塔石碑记录了多种古代文字之间的转译关系一样，智能设计工具也可以成为一种承载多种设计思想精髓的知识节点，或一种更便于理解和使用的通用设计语言，以造福所有的人类设计师。目前，以此为目标的研究已经展开^②，并已在设计小尺度现代主义风格建筑方面取得了一定进展（图2）。

2 人类与智能设计工具相辅相成

尽管智能设计工具的研发已经取得了可观的进展，但在目前的实际应用中，由于场地条件往往十分复杂，通常存在多种不确定因素，加之不同项目之间可能存在极大差异，因此仅依赖智能设计工具显

map of the industry — just like the ancient Egyptian Rosetta Stone that helped people learn the interrelations between different languages, intelligent design tools can act as a new library that collects the essence of various design ideas, or a common tongue that is easier to understand and communicate among human designers. So far, research targeted at this very field has already carried out^② and seen a progress in inspiring modern architectural styles of small-scale design practice (Fig. 2).

2 Humans and Tools Complement Each Other in Practice

Despite its significant progress, intelligent design tools also see inadequacies in dealing with complicated site conditions and uncertainties of authentic cases, as well as the great variety among projects. Experienced human designers are still

然无法妥善地应对这些情况。因此，在洞察场地问题、与用户沟通协商，以及最终设计决策等环节，有经验的人类设计师依然具有不可替代的作用。人与机器的密切协作将是智能设计工具发展中的长期议题之一。

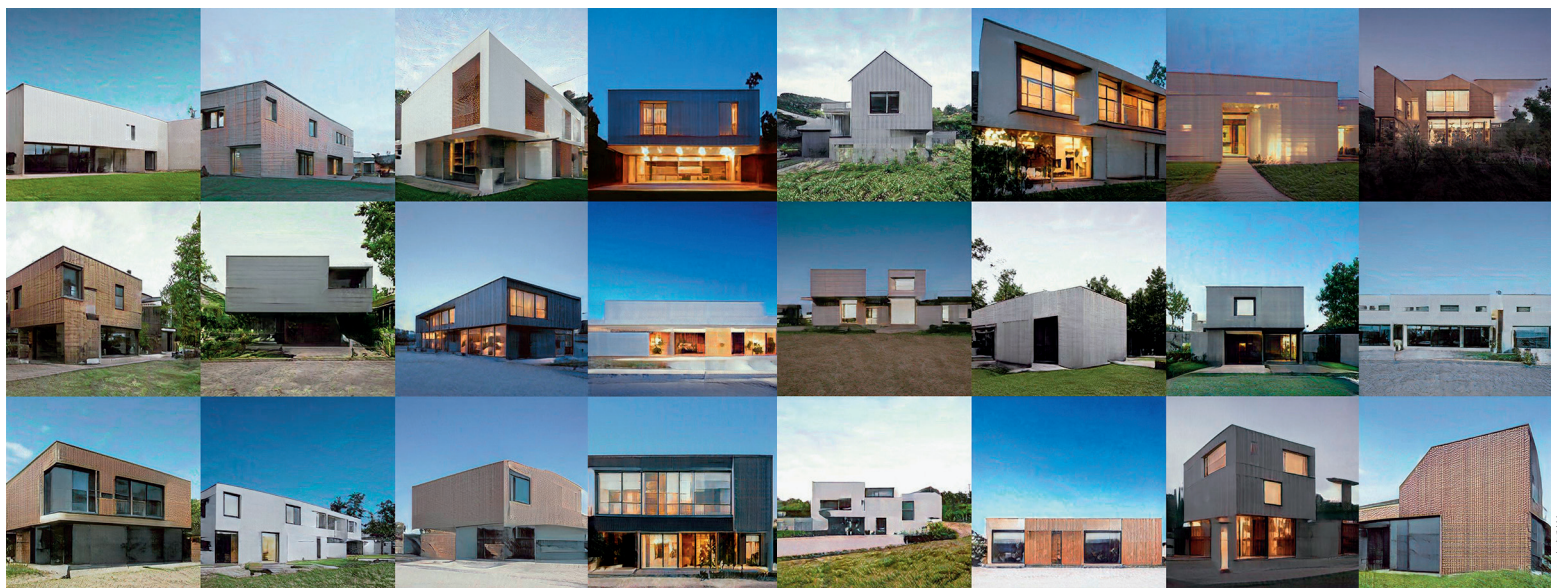
深圳湾生态科技园项目二标段的设计与建设较好地体现了这一点。在概念设计阶段，设计团队使用小库原型对项目地块未来的交通情况、人流动态以及空间格局变化之于城市的影响进行了分析，并提出了“多层连接”和“西密东疏”的建筑密度总体布局，以及“独立小型底商+上层多种空间组合”的建筑形态。该设计能够充分利用场地西侧优越的交通条件与东侧良好的景观，与传统模式的设计思路不谋而合（图3，4），最终赢得该项目的设计竞赛。在随后的实施过程中，为了便于业主后续商业招租，设计团队修改了上述设计方案中的部分交通流线，但保留了小库对主要交通体位置的判断以及多层叠加的连接布局方式。项目建成后，场地内总体实现了较好的交通流引导效果，基本达到了商业利润的预期目标，但仍存在建筑首层交通流线过于松散、行人容易迷路等问题（图5）。

未来，随着此类智能设计工具的应用越发广泛，研发团队可通过逐步积累用户方案大数据，在智能设计工具的运行规则中加入更多对现实因素的考量，以提升输出方案的综合效益与可行性，更好地为人

irreplaceable in terms of insight into site issues, communication with clients, and final decision-makings. The close collaboration between humans and machines will remain a long-term agenda in the development of intelligent design tools.

For example, XKool was used in the design and construction of the second bidding section of the Shenzhen Bay TechCity project. In the conceptual design phase, the design team used the XKool prototype to simulate the project's impact on the city in vehicle traffic, pedestrian flows, and spatial pattern. Based on the analyses, the team proposed an overall layout that was characterized by a multi-layered connection, an uneven building density, and an architectural form combining small-scale storefronts with multiple spatial design of upper floors. This proposal made full use of the existing superior circulation in the west part of the site and the sound landscapes in the east, which coincided with a human design pattern (Fig. 3, 4), and won the design competition of this project. In its implementation, in order to help facilitate the commercial leasing, the design team accepted the main traffic plan and the multi-layered connection layout in the XKool proposal, while improving part of the circulation design. After the completion, the overall traffic flow on the site was well organized, which helped basically realize the expected commercial profits. However, the circulation of the ground floor of the building was loose, where visitors often get lost (Fig. 5).

In the future, with the increasing application of such intelligent design tools, the development team can accumulate



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类设计师提供反馈与建议。因此，智能设计工具与人类设计师应互为补充、相互促进、共同发展。

3 智能设计工具在专业教育中的普及

相较于其巨大的潜在价值，中国设计专业院校教育对智能设计工具的接纳程度与探索积极性稍显不足，这种有意或无意的回避可能加剧设计专业教育与行业总体发展需求之间的脱节。但值得欣喜的是，一些设计专业的学生已经认识到智能设计工具的价值，并主动去学习如何运用它们完成课程设计或实习中的一部分基础性工作。对于设计教育的变革而言，这或许是一个良好的开端。

可以想见，当智能设计工具在设计专业院校的课堂上普及开来之时，越来越多的人将会意识到：大量的重复性工作与训练并非培育优秀设计师的关键。设计专业的学生或年轻设计师必须具备良好的思维习惯和分析归纳能力，才能及时对自己的工作进行反思，从而总结出真正有助于提升自身专业技能与职业素养的经验与教训。在智能设计工具的辅助下，设计师可利用节省出的精力与时间深入钻研设计的核心逻辑与理念，或参与更具创造性和公益性的实践项目，这或许更有利于其全面提升核心竞争力，并变得更加富有责任感与使命感。因

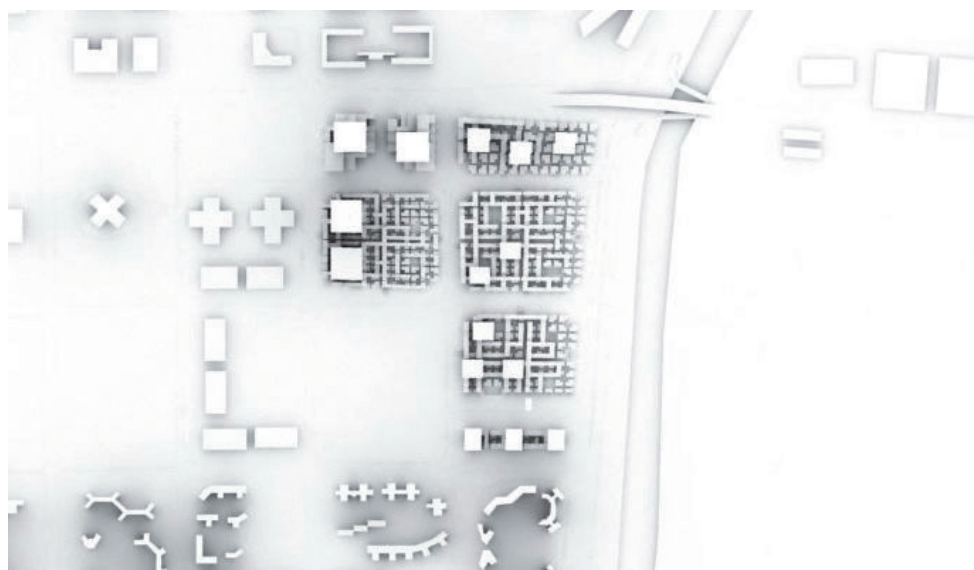
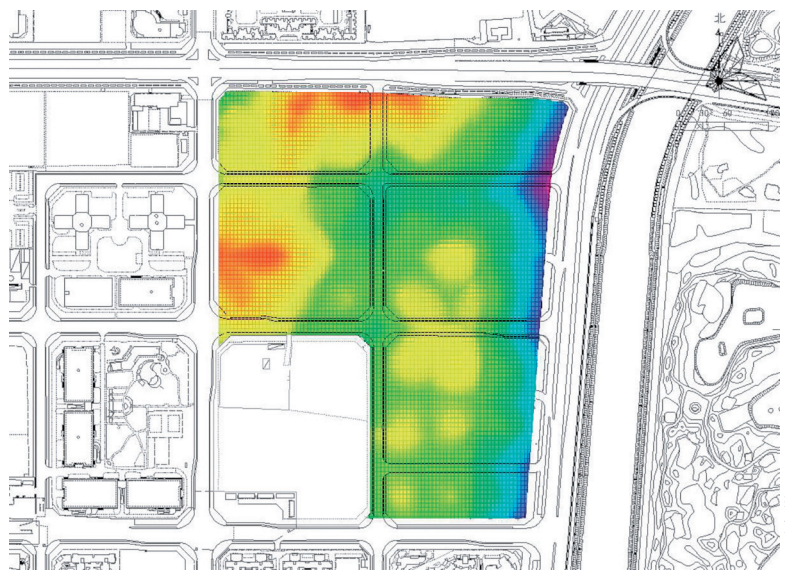
big data of user solutions, the algorithms would be improved by introducing more realistic factors for a greater overall benefit and practical feasibility of design solutions. The feedback and advice provided by intelligent design tools will better inform human designers. Therefore, intelligent design tools and human designers will benefit, complement, and promote each other for a mutual growth.

3 Intelligent Design Tools in Design Education

So far, intelligent design tools are less applied and explored in China's design colleges — intentionally or unintentionally — which may cause a bigger gap between design talent training and the overall development needs of the industry. The good news is, numbers of design students have realized the value of intelligent design tools and are actively seeking to use them in their course design or internship for groundworks. This may be a good start for the reform in design education.

It is predictable that as intelligent design tools become more and more popular in the classrooms of design colleges, an increasing number of faculties and students will realize that a good designer is not trained by lots of repetitive work. Design students and young designers must foster their thinking and inductive ability in order to reflect design experience and lessons, which would really help improve their professional skills. Intelligent design tools can free designers from repetitive

3. 深圳湾生态科技城竞赛阶段基地价值图
4. 深圳湾生态科技城竞赛阶段渲染顶视图
3. Site value analysis of the design proposal of Shenzhen Bay TechCity
4. Site top-view rendering of the design proposal of Shenzhen Bay TechCity



③ “未来建筑实验室”是一个面向城市设计与建筑设计、主要进行设计方法研究与未来城市探索的实验型设计与研究机构，与中国多家开发商、设计院及国内外科研院所或机构、科技公司等建立了合作关系，致力于从事新兴科技与城市、建筑结合方向的设计和研发。

③ Future Architecture Lab is an experimental design and research institute in urban design and architecture, with a focus on design method research and future cities. It has built cooperative relationships with a number of Chinese developers and design institutes and international and domestic research institutes, technology companies, etc. It is committed to the design and research by integrating emerging technologies with urban and architectural design.

此，我们大可不必担心将智能设计工具引入专业教育会导致年轻设计师无法得到足够的基础技能实践训练机会。

4 智能设计工具与相关设计学科协同发展

与传统建筑设计、景观设计以及城市规划等学科一样，运用智能工具进行设计的最终目标是为用户服务。因此，尽管当下人工智能辅助设计技术与中国设计专业教育体系的融合仍显不足，但后者长久以来深厚的学科积淀仍可极大地推动前者的演进。例如，在智能建筑设计工具的开发团队中，建筑师是不可或缺的力量：他们的专业知识与实践经验对于用户反馈分析和产品性能改进具有重要指导意义；此外，传统建筑设计学科本身也在不断发展，各类新理论与方法不断涌现，这也为基于人工智能的建筑设计提供了指导与启发，催生了以未来建筑实验室^③为代表的一系列设计研究机构。

除建筑设计外，城市规划、城市设计与室内设计等领域最终也都将走上与人工智能相结合的道路。这些领域都十分注重空间功能、人流动线，及使用者的空间体验，彼此间的差异主要体现在所聚焦的尺度及相关联的设计要素等方面。这些领域因为拥有相通的内在设计逻辑，因而有望将智能设计工具的应用尺度从当前的单一地块进一步聚焦到建筑单体，或扩展至街区乃至城市尺度。

景观设计与上述领域略有不同：如果将人类的生存环境看作一个多层次系统，景观则是其中一个较为特殊的层级，因为它有着颠覆整个系统的潜力。因此，在某种意义上，景观设计的逻辑与建筑、街区及城市尺度的设计恰恰相反：其将维护整个环境系统的完整性作为最重要的考量因素，而非以尽量满足人的需求或城市扩张需求为首要出发点。在此前提下，基于建筑的智能设计工具的开发逻辑可能无法直接沿用到景观领域。上述特性也间接导致景观设计学领域当前的数字化和智能化程度相对滞后于其他学科。但不可否认，这种跨学科、跨

groundworks, so they can spend more time on studying design logic and concepts, or engage into more creative and non-profit practical projects, which would help designers enhance their core competitiveness and grow into design professionals with a stronger sense of responsibility and mission. In my opinion, there is no need to worry that the introduction of intelligent design tools into design education will weaken young designers' essential skills.

4 A Synergetic Development between Intelligent Tools and Design Disciplines

Same as Architecture, Landscape Architecture, and Urban Planning, intelligent design tools are developed to serve the users in physical environment. Although the current design education has less applied AI-assisted design, it still can benefit the evolution of intelligent design tools by its long-history disciplinary asset. For example, architects are an indispensable force in the development team of intelligent architecture tools: their knowledge and practicing experience are significant for analyzing users' feedback and improving product performance. In addition, the discipline of Architecture itself is facing evolution and changes. Various emerging theories and methodologies also provide guidance for and inspire architectural design supported by AI, and have spawned a series of design and research institutions such as the Future Architecture Lab^③.

Other architecture-associated fields such as urban planning, urban design, and interior design will also increasingly engage with AI eventually. Besides the variety in scale and design element, these fields share a same set of design logics and all of them focus on improving spatial function, pedestrian flow, and users' experience through design methods. The application of intelligent design tools can extend from site scale to architectural, neighborhood, and urban design realms.

Landscape design, however, slightly differs from the above all — if the human living environment is viewed as a multi-level system, landscape lies on a special position because it shows a potential to subvert the entire system. In a sense, the logic of landscape design is exactly reverse to the design of buildings, neighborhoods, and cities: instead of pursuing a maximum satisfaction to human desires or a greatest urban growth, landscape design is to maintain the entire eco-environment of human settlement. This means that landscape design professionals cannot adopt the existing intelligent design tools from Architecture, which also results in the fact that the current digitalization and intelligence level in Landscape Architecture is lagging behind that of other disciplines. Even so, such



5. 深圳湾生态科技城二标段建成照片
5. The completed second bidding section of Shenzhen Bay TechCity

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尺度的尝试有助于设计师建立审视人类生存环境的新视角，眼下的一些理论与技术障碍终究无法阻挡智能设计工具在更多尺度、更广领域内发挥作用，无论是建筑师、景观设计师还是城市规划师，都不妨积极看待这一趋势。

5 乐观面对智能设计工具发起的“岗位竞争”

综上所述，即使智能设计工具的出现对人类设计师的价值发起了挑战，这种挑战仍然是一种良性竞争，这是由智能设计工具的本质特征与功能定位决定的。例如，目前小库主要定位于占设计市场总量70%左右的房地产开发类项目，对于剩余30%建造要求更高的公共建筑或改造优化类项目仍有赖人类巨大的创造力。发展智能设计工具的真正目

interdisciplinary, cross-scale reference offers designers new lenses to re-examine human living environments. Current temporary theoretical and technical difficulties would not hinder intelligent design tools playing roles in more scales and broader fields. Architects, landscape architects, and urban planners are expected to engage themselves with it.

5 Intelligent Design Tools: From “Competitors” to “Co-Workers”

From the above, the challenge by intelligent design tools to the role of human designers brings a healthy competition, due to the essential features and orientation of intelligent design tools. XKool, for example, is conceived to mainly serve real estate development projects, accounting for about 70% of the total design market; the rest including public buildings and renewal projects requires a more comprehensive consideration and coordination and a greater creativity, where human designers play their roles. I believe that the emergence of AI design tools inspires human designers and

的是激发人类设计师的独立思考与创新能力，以及自主探索的欲望。这种解放甚至将进一步推动业界对设计哲学的反思与探讨，进而加速设计学科的转型与行业的升级。

就整个设计行业而言，智能设计工具对经典设计范式或理念基础发起的挑战也具有一定的积极影响。智能设计工具的繁荣发展未必会造成“匠人精神”的消逝：前者更加注重设计效率，能高度适应工业化社会批量生产的需求；后者则更强调设计的独特性或个性，反映了一种精益求精、持之以恒的态度。这两种模式各自代表的设计价值观并非完全对立，而是互为补充，在多样化的市场需求下，它们将继续共存下去。

就建筑设计与城市规划领域而言，注重经济利益的商业类项目可能更倾向于使用前一种模式，而公共建筑设计、城市更新和历史文化街区保护等项目则可能更适用后一种模式，以便最大限度地协调各方利益，充分传达场所精神、延续地方文脉，从而提高项目的综合品质与公共效益。此外，“匠人精神”也可以看作是个人独特思维逻辑与表达方式的一种体现，是高度智能化时代设计师必须具备的重要能力之一。因此，这种精神在未来或将变得更为重要。**LAF**



encourages them to think critically, work creatively, and explore proactively. This will further promote professionals' reflection on design philosophy, the transition of design disciplines, and the upgrading of the industry.

Moreover, to the design profession, the challenge by intelligent design tools also brings more reflections on classic design paradigms and ideologies. However, its boom does not necessarily compromise the design craftsmanship: intelligent design tools improve design efficiency and work with mass production in industrialized societies; design craftsmanship emphasizes the uniqueness, individuality, and refinement of design. The values respectively represented by these two are not completely opposite but complementary. They will continue to associate with each other for the diversified demands in the profession.

Specifically, in the fields of Architecture and Urban Planning, commercial projects that seek for a larger economic interest may benefit more from intelligent design tools, while design craftsmanship would be suitable for elaborating public building, urban renewal, and historic and cultural preservation projects, allowing for a better coordination of the interests of all stakeholders, a celebration of the spirit of the place and local context, and an improvement of the overall quality and public benefits. In addition, the design craftsmanship can also manifest designers' unique thoughts and expression — an important skill that a designer must regain in this intelligence era and an estimable professionalism for the new generation of designers. **LAF**

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- [1] He, W. Y., & Yang, X. D. (2018). Artificial Intelligence Design, from Research to Practice. *Time + Architecture*, (1), 38-43.

