# 数字工厂

## 高级计算性生形与建造研究

# DIGITAL FACTORY

## ADVANCED COMPUTATIONAL RESEARCH

## 学生建筑设计作品

## DADA 2015 STUDENTS

徐卫国 / 尼尔 · 林奇（英） 编

Xu Weiguo / Neil Leach [eds.]

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中国建筑工业出版社

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徐卫国 尼尔·林奇（英）编

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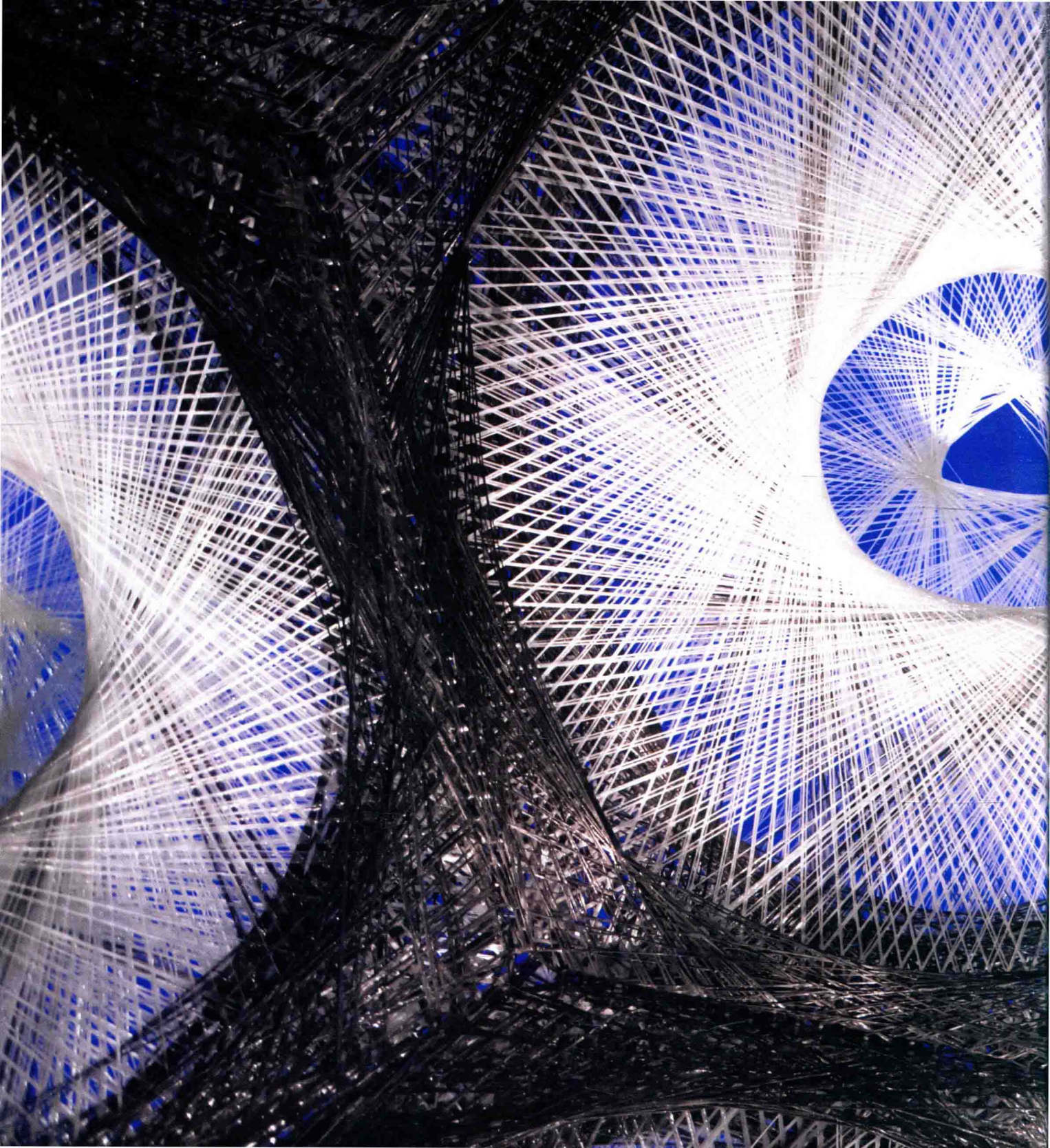

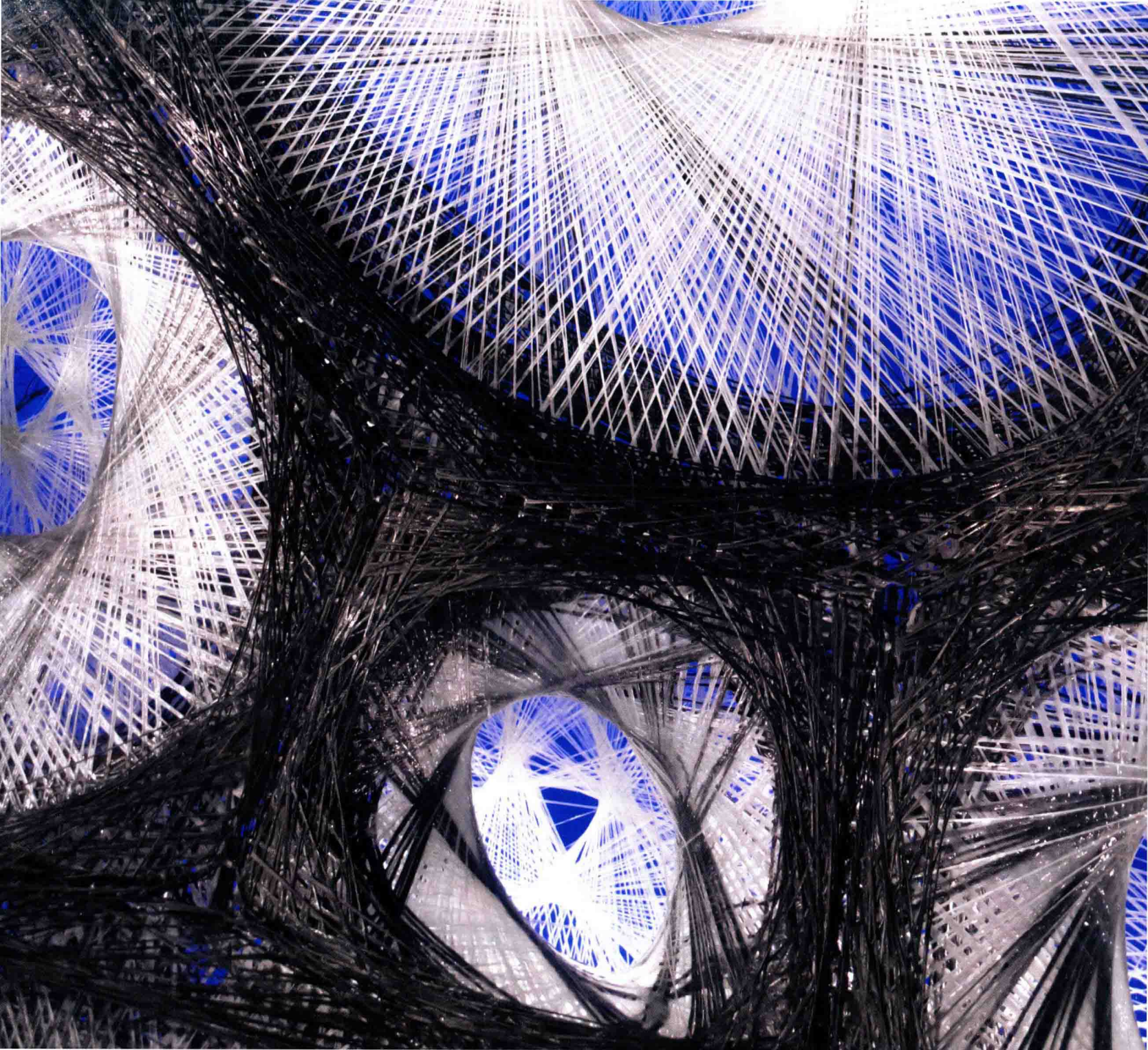

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# 前言 / PREFACE

本作品集收录了在上海同济大学建筑与城市规划学院举办的“数字工厂：高级计算性生形与建造研究”学生作品展中的作品，该展览为 DADA2015 系列活动之一，其余的活动包括一系列的工作营与国际会议等。

自 2004 年起，徐卫国与尼尔·林奇合作策划了一系列的数字建筑展览。第一次是 2004 年在北京 UHN 国际村为北京建筑双年展举办的“快进 >>”展。之后 4 次分别是 2006 年在北京世纪坛举办的“涌现”展，2008 年和 2010 年在北京 798 时态空间举办的“数字建构”展和“数字现实”展，以及 2013 年在北京 751 举办的“设计智能：高级计算性建筑生形研究”展。本次展览是往届合作策展的延续。

本作品集收录了一些世界顶尖建筑院校最高级的计算性设计作品。这些学校包括英国建筑联盟建筑学院、哈佛大学设计研究生院、麻省理工学院、斯图加特大学、伦敦大学、清华大学和同济大学。至此，本次活动呈现出各个建筑院校持续增长的对于计算性建筑研究的兴趣爱好，并且提供了非常有用的该领域近期发展的剪影，与先前的活动共同展现出该领域的发展全貌。

This is a catalogue of works on display in the 'Digital Factory: Advanced Computational Research' exhibition of student work at the College of Architecture and Urban Planning, Tongji University, Shanghai, as part of the DADA 2015 series of events. Other events in DADA 2015 include a series of workshops and a conference.

Since 2004 the curators, Xu Weiguo and Neil Leach, have collaborated on a series of digital design exhibitions. The first exhibition, 'Fast Forward>>', took place in UHN, Beijing in 2004 as part of the Architecture Biennial Beijing. This was followed by four further exhibitions, 'Emerging Talents, Emerging Technologies', in the Millennium Museum, Beijing in 2006, '(Im)material Processes: New Digital Techniques for Architecture' in 798 Space in 2008, 'Machinic Processes' in 798 Space, Beijing in 2010, and 'Design Intelligence: Advanced Computational Research' in 751 D-Park, Beijing in 2013. This exhibition is a continuation of that collaboration.

This catalogue offers a showcase of the most advanced computational design work from some of the leading schools of architecture in the world. These schools include the Architectural Association, Harvard University GSD, MIT, University of Stuttgart, The Bartlett, Tsinghua University and Tongji University. As such, it serves to track the continued growth of interest in computational research in schools of architecture, and provides a useful snapshot of recent developments in the field that adds to the collective overview provided by previous exhibitions.



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2015 年的展览有一个非常重要的特征，那就是机器臂建造受到极大的关注。实际上，这种情况不仅仅发生在早已有机器臂的那些学校；在中国，像清华大学和同济大学这样的顶尖院校，现在也配置了机器臂；这说明中国大学的建筑专业已处于世界建筑学发展的前沿。

最后，策展人对所有为作品集做出贡献的人致以最诚挚的谢意。特别感谢刘畅、张鹏宇、刘春、刘洁、秦承祚、金旖、张自牧、刘剑颖、张弛和时思芫等为作品集的设计、翻译和材料整理所做的工作；同时，对提交作品的院校致以谢意。

尼尔·林奇
徐卫国

One significant feature of this year's exhibition has been the increasing popularity of robotic arms used in fabrication. Indeed it is not only the more established Western schools that have acquired robots. Leading schools in China, such as Tsinghua University and Tongji University, have also now acquired them, illustrating the remarkable speed at which Chinese schools of architecture have been catching up with the rest of the world.

The curators are grateful to all those who have contributed to the preparation of this catalogue. In particular, they would like to thank Liu Chang, Zhang Pengyu, Liu Chun, Liu Jie, Qin Chengzuo, Jin Yi, Zhang Zimu, Liu Jianying, Zhang Chi and Shi Siyuan for their invaluable contribution in helping to design, translate and compile material for this exhibition, and to the schools themselves for submitting that material.

Neil Leach
Xu Weiguo

# 对话 / DIALOGUE

## 徐卫国—尼尔·林奇

## XWG-Neil Leach

*徐卫国（以下简称徐）：去年深圳 DADA 核心会员会议决定 2015 年系列活动由同济承办、袁烽负责，并确定活动主题为“数字工厂”。我想这一主题包含了多层含义：其一，DADA 试图推动数字技术从数字设计向数控生产发展；其二，建筑业应该以数控加工作为产业升级的目标；其三，建筑的数控建造应该能响应新兴工业 4.0 的崛起，并携手探索智能建筑工业的道路；其四，DADA 有责任召唤建筑师站在新一轮工业革命的前列，引导数字建筑产业的诞生及健康发展。这是“数字工厂”这一命题的含义。您对这个题目作何想法？*

Neil Leach（以下简称 NL）：我认为这个题目非常适合一个位于中国的展览。首先，所有人都知道目前世界上很多商品都是中国制造的。中国已经成为了世界工厂，因此在中国举办这个展览非常合适。但是在此背后，这个题目试图传达的是对于实际生产的关注。工厂毕竟是一个主要追求生产效率最大化的实体，中国作为建筑行业中的领先大国，在数字加工的领域也产生了越来越多的对于数字技术与实际生产相结合的关注。例如，像 E-Grow 这样的公司已经出现在我们的视野中有一阵了。E-Grow 是西方领先的建筑公司，为扎哈·哈迪德及墨菲西斯在中国的项目提供数字生产的面板系统。同样，我们也可以引用最近在中国三维打印出来的住宅作为一个例子，尽管它所使用的技术仅仅是由南加州大学克什涅维斯教授所发明的轮廓工艺的简化版本，但是在中国尝试此类项目本身仍然具有很大意义。另外，中国目前也有计划依照克什涅维斯教授的技术制造原型机。现在 3D 打印现象随着建筑师跨界到其他创意领域已经蔓延至整个中国。例如，由 OMA 创始人雷姆·库哈斯的侄子雷姆·D·库哈斯创立的 United Nude。它目前在广州并与 UN Studio、扎哈·哈迪德等前卫的设计师事务所合作生产 3D 打印的鞋子。与此同时设计师马子聪也在上海创建了自己的事务所，专注于设计三维打印的首饰及可穿戴物。

目前，数字加工在中国学术圈内同样扮演着越来越重要的角色。机械臂也被引入中国的若干所建筑院校之中。就像它转变了一些西方学校的教育模式一样，它也同样改变了中国的建筑教育。同

XWG: Last year, Tongji University was selected to host DADA 2015 event series in the core members meeting of DADA. The theme for the DADA 2015 events was decided to be "Digital Factory". There are many layers of meanings related to the theme. First, DADA is promoting the focus of digital technology to migrate from digital design to digital production. Secondly, digital production should be the direction of the future upgrade of building industry. Also, under the inevitable rising of industry 4.0, the CNC building construction will take on the road to discover the future of intelligent building industry. Lastly, DADA should be responsible for calling architects to make efforts to lead the development of digital building industry. What do you think about the title?

NL: I think that it is a very good title for an exhibition opening in China. To begin with, everyone knows that China produces many of the goods in the world right now. As such, China has become the world's factory, and it therefore seems very appropriate to hold this exhibition in China. But – beyond this – the title seems to convey a certain focus on practical production. Factories, after all, are primarily practical spaces dedicated to efficient production. This interest in practical productions itself reflected in the digital fabrication processes that are playing an increasingly significant role in what has also become one of the leading countries in the world in terms of building construction.For example, we have known about companies like E-Grow for some time now. E-Grow has supplied digitally fabricated paneling systems for leading Western architects operating in China, such as ZahaHadid Architects and Morphosis. We might also cite the example of the houses that were 3D printed recently here in China.While the technique used was essentially a simplified version of the Contour Crafting technique invented by BehrokhKhoshnevis, a professor of engineering at the University of Southern California, it is nonetheless significant that there here in China is the will to attempt such a project. Also there are now plans to prototype ProfessorKhoshnevis's technique in China.Indeed the phenomenon of 3D printing has now begun to spread throughout China as architects become involved increasingly in other creative industries.For example, United Nude – the company set up by Rem D Koolhaas, nephew of the more famous founder of OMA – is now operating out of Guangzhou, producing 3D printed shoes in collaboration with several leading architects, including UN Studio and ZahaHadid Architects, while Steven Ma has opened up an office in Shanghai, focusing on 3D printed jewelry and wearables.

Meanwhile digital fabrication is also playing an increasingly significant role in Chinese academic

时，DADA 的队伍也越来越壮大。2015DADA 数字工厂研习班将一批极具天赋的教师聚集在了一起。事实上，我甚至不知道任何一所西方的学校可以如此自豪地引入一批世界级的教授来研习班授课。令人瞠目结舌的是这里同时有阿希姆·门格斯、罗兰·斯努克斯、马德朴、约翰·布朗曼以及雷姆·D·库哈斯这样的西方的领军人物及中国的代表袁烽、于雷、宋刚、马子聪等并肩教学。

另外，数字未来系列图书的最新一本《人机未来》出版了，并在上一本《制造未来》的基础上带来更进一步的贡献。所有的这些进步都表明了不仅仅在建筑建造中，更是在学术及研究领域，中国已经成为数字生产制造界的中心。中国已经成为建筑生产领域新的数字工厂了。

*徐：那么，总体而言，在数字设计的发展方面，如果您把中国和西方进行对比，将得出什么结论？*

NL：我记得当 2004 年，我们共同策划第一个展览的时候，我们为它取名为“快进 >>”，这个名称来源于在录音播放机上用于加快播放的按钮。但是那时候中国的建筑文化同计算机的交会很少，甚至说那时候几乎在中国建筑界，大家从未听说过编程，所有的事情都很原始；但是到了我们上一个 2013 年的“设计智能：高级计算性建筑生形研究”展览的时候，中国已经发展出了非常成熟的数字设计文化。实际上，我甚至能想起当马克·贝瑞 ( 他曾受邀参加我们 2004 年第一届的展览 ) 坐在我们 2013 年的 DADA 会议现场的第一排时，他看上去被当时的所见所闻震惊得合不拢嘴。他最后转过身来对我说：“我要回到澳大利亚告诉我的同事们，我们已经没有任何东西可以教给中国建筑师了。”我不太确定他的话是否有一定的夸张，但是这确实导致我反思我们最早的题目“快进 >>”以及不同的快进速度。当我们提出这个题目的时候，我脑海中是 4 倍甚至 8 倍快进的速度，但是事实上我们观察到的却是 16 倍甚至 32 倍的快进速度。在中国，数字设计的追赶及发展速度令人震惊。

在 2004 年之后，另外一个中国发展的分水岭是 2008 年。这一年的标志是为了北京奥林匹克运动会，鸟巢及水立方两个代表性的

circles. Robotic arms have now been introduced into several schools of architecture here, thereby transforming Chinese architectural education in a way that it has already transformed several schools in the West.Meanwhile, the DADA initiative has gone from strength to strength. The 2015 DADA Digital Factory workshops are remarkable for the range of talented instructors that they bring together. In fact I don't know of any Western school that could boast of the same array of world-class professors teaching workshops. To have leading Western figures, such as Achim Menges, Roland Snooks, Matias del Campo, Johannes Braumann, and Rem D Koolhaas, running workshops alongside leading Chinese figures, such as Philip Yuan, Yu Lei, Gang Song, Steven Ma and so on, is an astonishing development.

Moreover the publication of Robotic Futures, - the latest in the Digital FUTURE series of books that builds upon our earlier publication, Fabricating the Future – makes a further contribution. All these developments only demonstrate– not only in terms of building construction, but also in terms of both pedagogy and academic research – that China is now playing a central role in the development of these digital fabrication techniques. China has become the new digital factory for architectural production.

*XWG: These changes in education will help the rapid forwards in 'Digital Factory' in China.Generally, how do you think in the developments of digital design, if comparing china to the West?*

NL: I can recall that back in 2004 when we curated our first exhibition we called it 'Fast Forward>>', as a reference to the control button on most audio-visual systems that allows one to increase the speed of that system. But in those days Chinese architectural culture had hardly engaged with computation. Indeed it seemed that no one in architectural circles in China had even heard of scripting.Everything was very primitive. But by the time of our last exhibition in 2013, Design Intelligence: Advanced Computational Research, China had already begun to develop quite a sophisticated digital design culture.Indeed I can recall seeing Mark Burry – who had been invited to that first exhibition back in 2004 – sitting in the front row of our 2013 conference, and it looked as though his jaw dropped in incredulity at what he was seeing. He subsequently turned to me and said, 'I have to go back to Australia and tell my colleagues there that there is nothing that we can teach these Chinese architects any more.'I'm not sure if this is strictly true, but it did cause me to reflect on our original title, 'Fast Forward>>', because in fact there are many different rates of 'fast forward'. I had been thinking in terms of 4 times, or even 8 times as fast.

计算机设计的建筑的诞生，同时期还有 OMA 的 CCTV 大楼。在鸟巢的设计当中应用了 Digital Project 软件，即第一个建筑信息建模技术的案例；其中，Digital Project 被用来控制每条放样曲线的定位，并通过将所有的建造信息融合进一个数字模型里的方式来控制造价以及建造周期。另一方面，很明显的变化是建筑设计事务所开始大量投入自己的计算机研究团队。例如诺曼·福斯特事务所的特殊建模团队（SMG）、奥雅纳公司内部的高级几何团队（AGU），以及扎哈·哈迪德事务所的 CODE 小组等。实际上，奥雅纳作为工程咨询公司，参与了上面提到的两个项目；AGU 小组的资源也得到了充分的利用。同样的，盖里科技也作为顾问参与到了鸟巢的设计建造之中。现在，计算机的应用已经是重大工程必不可少的一部分了。我之前提到的关于工厂的参考，实际上它目前已经成为实际生产中必不可少的一环。同时，计算机工作营与从前仅仅利用计算机技术将传统的设计过程数字化不同，现在的工作营尝试利用电脑技术生成设计。目前中国有非常多类似的工作坊，他们吸引来了大量的中国学生，袁烽和我甚至决定出版一本叫做《数字工作营在中国》的书。2008 年注定了计算机技术将在中国扎根。

*徐：刚才你用 2004 年我们策展的“快进 >>”展览题目来形容中国数字设计的发展，这非常形象、非常确切。事实上，近十年来，中国已经形成了数字建筑设计师群体，我们称其为“数字新锐”，他们都有实际建成项目，这些建成项目充分依靠和展现了数字技术的潜能。比如北京市建筑设计研究院邵韦平设计的凤凰卫视北京媒体中心，在设计完成度、设计的细节、设计的过程逻辑、材料的使用，以及结构的合理性、构件加工及施工的精确度等方面都可以说达到了世界最好，大家更喜欢凤凰卫视的亲切及细腻，我甚至把它与哈尼·拉什德的阿布扎比 YAS 酒店进行了比较（去年有机会入住 YAS 酒店），凤凰卫视要比 YAS 酒店好很多。此外，张晓奕设计的阿里巴巴杭州总部大厦、林秋达设计的厦门第三国际航站楼、宋刚设计的佛山艺术村、王振飞设计的青岛园博会服务设施建筑等，都是数字技术的成果，中国宏大的建设规模以及开放的社会心态使这些年轻建筑师有机会在实践中展示才华，他*

In fact I think that what we have witnessed has been in the order of 16 or 32 times as fast. It is astonishing how quickly digital design has caught on in China.

After 2004 the next watershed moment – at least as regards China – was 2008, a year that marked the completion of not only two highly computationally designed buildings for the Beijing Olympics, the 'Birds' Nest Stadium' and the 'Water Cube', but also the construction of the OMA's CCTV building.On the one hand, Digital Project – one of the first examples of Building Informational Modelling (BIM) – had been used in the Bird's Nest Stadium to control not only the precise definition of the curves employed, but also to control the cost and time of construction by integrating all construction information on a single digital model, that could be updated relatively easily.On the other hand, it was clear that architectural offices were beginning to invest heavily in in-house computational research units, such as the Specialist Modeling Group (SMG) at Foster and Partners, or the Advanced Geometry Unit (AGU) at Arup, or CODE at ZahaHadid Architects, and so on.In fact Arup was the consultant engineering firm for both projects, and the resources of the AGU were used extensively. Likewise Gehry Technologies were involved as consultants for the Bird's Nest stadium. By this time we had reached the stage that computation had become seemingly indispensable in any major construction project. In terms of my earlier reference to factories, it had become a practical necessity in terms of production.Meanwhile computational workshops – that sought to harness the capacity of the computer to generate designs, rather than simply as a 'computerization' of the culture that existed before the introduction of computers – began to spread like a virus all over China. Indeed there were so many computation workshops attended by so many Chinese students, that Feng Yuan and I decided to publish a book about the phenomenon, Digital Workshops in China. By 2008 it was clear that computation was here to stay.

*XWG: You have just used the word "Fast Forward>> " in the exhibition of 2004 we curate together to descript the development of digital design in China. This is very accurate. In fact, in last decade, a new group of digital architects are emerging, called "Digital Advanced". They all have practical projects realized relying on the digital technology. For example, the media center for Phoenix TV in Beijing designed by Shao Weiping of Beijing Institute of Architecture Design, many aspects including the level of completion, design details, logic design process, the selection of materials and structure system, component fabrication and construction accuracy have reached the top level in the world. People like the exquisy and friendliness of Phoenix Center. I have even compared it to the YAS Hotel in Abu Dhabi by Hani Rashid as I had the stay there last year, and*

*们将引领数字建筑设计的未来。*

NL：但是，对于数字设计及生产建造本身而言，过去几年曾有过一个概念上的巨大转变。在 2004-2008 年这段实践中，对于数字工具的使用主要是在外形及表现上，计算机大多数时候被用于作为一个产生新的美学形式的工具，在那之后我注意到了关注点由表现形式到过程及性能的转变。我先要用“形体”的词根（form）来讨论。我们一方面可以用“为了形体而找形”又或者我们可以从更高、更成熟的角度将形体（form）延展到以它为词根的单词上，例如“性能”、“活跃度”及“信息”。这样，问题就变成了“表现”如何能够“影响”到“形体”，这在中国虽然并不是一个随处可见的设计浪潮，但是数字设计界的一些带头人已经开始向这些方向转变；同时，在西方由性能引导设计方向的带头人阿奇·蒙哥斯也在中国越来越有影响力。

*徐：是的，这一点在建筑设计教学上表现得尤为突出，比如清华的数字设计工作坊已有十年的历史。开始的时候侧重于用软件和算法生成形态，但现在已完全基于建筑的性能条件，如环境因素、人的动态行为，以及相互间的互动等等，并在寻找基本联系的前提下运用参数模型进行设计生成，其结果可以直接满足设计需求并与环境之间建立友好的联系。对这些学生进行训练，使他们建立起更科学的建筑设计观；而当他们毕业工作后，他们新的设计思想又影响了设计实践；有一些学生会去西方留学，他们也将影响到西方的建筑教学。*

*换一个话题，我们来谈谈“风格”的问题，之前您似乎谈到过，用“风格”来评判数字设计是不合适的，能否再谈谈对这一问题的看法？*

NL：不，完全不合适。我认为将计算机设计定义为一个建筑风格是错误的，我不同意舒马赫所言的有一个名为参数化主义的全球性建筑风格，并且其特点是曲面建筑。我在 2010ABB 会议纪要上曾经写过一篇文章，深入探讨了“参数化主义”的定义及技术上的误用，在我们当今的大环境之下讨论这种全球通用的概念已经没有太多的意义了。在现代主义倒塌之后此类的概念与利奥塔提出后现代主义中“辉煌叙事”的倒塌相背驰。同样的，对于风格

*found that the Phoenix center is much better. Also the Alibaba headquarter in Hanzhou by Zhang Xiaoyi, Terminal 3 of Xiamen Airport by Lin Qiuda, Fushan Art Village by Song Gang, the service facilities of Qingdao Gardening Expo are all the examples of application of digital technology. The massive construction going on in China and the open minded society provide opportunities for these young architects to reveal their talent in practice. They will lead the future of digital architecture design.*

NL: But I think that there has also been a significant shift in terms of the nature of digital design production. In the 'old days' – if we can refer to a period as recent as 2004-2008 in that way – the interest in digital tools operated primarily at the level of representation. The computer was largely a tool for producing a new aesthetic. What I have noticed since then has been a shift away from mere representation towards process and performance. I like to think of this in terms of the word 'form'. We can either think of 'form' in terms of 'form for form's sake'. Or we can think of it at a more sophisticated level in terms of a series of other terms that also include the word 'form', as in 'performance', 'performativity' and 'information'. The question now is how issues such as 'performance' can 'inform' that 'form'. This is by no means a universal phenomenon in China, but some of the leading figures in digital design, are beginning to think more in these terms, and the work of AchimMenges, who has been a pioneer of performance driven design in the West, has come to be recognized as highly significant here in China.

*XWG: Yes, This is very explicit especially in architecture education. For example, the digital design studio in Tsinghua University have been ongoing for 10 years. At the earlier stages, it was more focused on software application and algorithm form generation. But now it has been based on the architecture performance, such as environmental factor, human behavior and interaction etc. And the parametric models are based on those basic connections among different factors . The result of the generating will directly bridge the design requirements and the environments. This makes students establish a more scientific design method. After graduation, their design method will in turn influence design practice. Some of the students who will be studying abroad have brought new knowledge to western education.*

*For the issue of "Style", do you think of digital design as being a question of 'style'?*

NL: No. Not at all. I think that it is a mistake to think of computation in terms of a new 'style' for architecture. I certainly disagree with Patrik Schumacher, who claims that there is a new global style of architecture, called 'Parametricism', that is characterized by its curvilinear forms. I have

等问题的过度关注又貌似是一个后现代主义的趋势，因此，舒马赫被困在现代主义和后现代主义之间。同样，舒马赫将计算机出现之前所生成的形体同计算机出现之后所生成的形体混为一谈，由此将曲线形体的出现完全归功于计算机的使用也是毫无意义的。这有些类似于人们曾经攻击计算机设计的肤浅、表面性及缺少内涵，而且我们已经在如《向拉斯韦加斯学习》这类出版物中看到了现有的整个由肤浅和表面性构成的文化。

对我个人而言，计算机仅仅是个工具，同时也是建筑想象力的延展。就它本身而言并没有固定的倾向，因此它并不能导致建筑师以某些特定的方式工作。但正如 J·吉普森所言，它具有一定的易上手性，即通过它的使用使设计师得以更加便捷地做出一些操作。例如，以前的平行尺几乎不可能绘制出一条曲线的控制线。当我在剑桥读书的时候，我们使用的是一种“法式曲尺”，即一种可以弯成曲线的软尺，但是我们没办法确切地理解这条曲线背后的逻辑。约恩·伍重在设计建造悉尼歌剧院的时候，结构顾问为奥雅纳，为了能够有效理解屋顶的自由曲线，不得不将其简化为一系列的球面。当然，在计算机出现之前我们也能创造曲线的造型，区别仅仅是现在通过计算机的应用，我们能够更简单地控制曲面，曲面形体的数字建造也是类似的情况。回想起 2006 年，我们曾经试图依照电脑画出的图纸，靠手工工具加工出 AAB 2006 的展亭，而在理想情况下，展亭应当用计算机数控机床（CNC）来加工，但是那时候在中国找不到这样的机器，于是我们使用了大量的建筑工人来手工切割出所需形体构件。最终，就像上面所提到的，控制的问题延伸到了整体的施工当中，其中 BIM 技术颠覆了建造过程中预算及工期控制的逻辑。

计算机的使用可以使类似的工作更加便捷。由此，我们可以观察到数字设计受到了一些共同影响，但是本质上，我不认为计算机的使用导致了一种新的风格的产生。与其说是风格，不如说计算机的使用使得人们可以更加轻易地做出一些特定的操作。例如，当今在线订机票远远比去中介公司更方便，结果便是计算机的普及导致了航空业的发展。更进一步来说，人们甚至可以将由越来

gone into the technical misunderstandings of the term, 'Parametricism', in my essay in the 2010 ABB catalogue. Also it makes no sense in our contemporary condition to talk about universal concepts.Following the collapse of Modernism such ideas are incompatible with what Jean-Francois Lyotard has called the collapse of 'grand narratives' in our Postmodern age. Equally to focus on the question of style seems to be a highly postmodern tendency.SoPatrik is trapped somewhere between Modernism and Postmodernism.ButPatrik also confuses the forms that were generated before the introduction of computation with those that were produced afterwards, and – as such – it makes no sense to attribute curvilinear forms purely to the introduction of the computer. It's a bit like those that attack computation as being superficial, shallow and meaningless, when we already saw the rise of a culture of superficiality with the publication of Learning from Las Vegas.

Personally I see the computer as just a 'tool', but a very sophisticated tool that becomes an extension of the architectural imagination. In itself it has no agency, and therefore cannot cause an architect to operate in any particular way.But it has certain 'affordances' – as J JGibson would put it – that makes it easier for the designer to perform certain operations. For example, in the old days of parallel motion drawing boards it was almost impossible to control the line of a curve. When I was a student at the University of Cambridge we used to use a 'French Curve' – a kind of flexible ruler that could be bent in the form of a curve – to describe them.But we had no way of knowing precisely the logic of that curve. Indeed it is significant that for JornUtzon's Opera House in Sydney the consultant structural engineers, Arups, had to reduce the freeform curves of the roof to a series of segments of spheres in order to understand them.Of course, we had curvilinear forms before the computer.It's just that it is easier to control curvilinear forms using a computer. And the same goes for constructing curvilinear forms using digital fabrication. As you recall, in 2004 we attempted to manually fabricate a pavilion for AAB 2004 based on computational drawings. Ideally the pavilion should have been fabricated using a Computer Numerically Controlled (CNC) milling machine, but we did not have access to one in China at that time, and instead employed an army of construction workers to manually cut the forms. The result was a disaster.Finally, as mentioned above, the issue of control extends to the overall construction, in that BIM has revolutionized the logistics of construction in terms of controlling cost and time.

So the computer makes it easier to perform certain operations. As such one can maybe recognize certain common affects in some digital designs. But – fundamentally – I do not think that the



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