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Building Information Modeling: An Innovative Process for Better Integration

建筑信息模型：优化集成管理过程的先进方法

Jun Su

Abstract

This article based on the analysis of the constraints of traditional 2D design and construction to current architectural creation and production quality. It summarizes BIM technology as a new means of digital design which is a technological innovation compared to traditional design and construction (especially to high-rise steel structure buildings with complex shapes). It not only breaks the shackles of long-standing restrictions on architectural form and space creation, but also closes the collaboration gap between design and construction.

Keywords: High-Rise Buildings, BIM, Parametric Design, CNC Machining

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苏骏先生作为上海建筑设计研究院数字建筑集成设计与咨询中心（BIM/VDC Center）主任，当前管理着多个大型 BIM 工程项目，并负责建筑全生命周期咨询与项目管理工作。同时还负责本中心的业务发展，包括项目策划与建议编制，工作范围评估，合同谈判与投标事宜等。数字建筑集成设计与咨询中心（BIM/VDC Center），前身为上海建筑设计研究院技术发展部下属BIM专项团队，是专门从事BIM/VDC等数字化设计与虚拟建造技术研发与咨询的专业机构。数字中心整合了上海院各专业的人才与技术优势，形成了以数字化、集成化、性能化为专长的研究与咨询服务梯队，依托上海院60年来的雄厚技术实力和市场口碑，为国内与海外客户提供一流的数字化技术咨询服务。

摘要

本文在分析了传统二维设计与建造方式对当前建筑创作与生产质量制约的基础上，简述了建筑信息模型技术作为一项崭新的数字化手段，对于传统设计与施工（尤其是体形复杂的高层钢结构建筑）是一次技术革新。不但打开了长久以来限制对建筑形态和空间创作的枷锁，更使得设计与施工变得合作无间。

关键词：高层建筑、建筑信息模型、参数化设计、数控加工

Project Case Study

Huzhou Hilton Resort & Hot Springs Hotel (see Figure 1) is 101.2 meters high and 116 meters wide. It is a ring shaped building and aims to become a platinum seven-star hotel. From a structural design perspective, all of the structural members are curved except for the core. This has a remarkable impact on the computational modeling of the structural design and future construction setting position. Through the analysis of the irregularly shaped volume model with the digital technology during the concept design phase, both u and v curve lines of the curved surfaces have been generated. The coordination of the intersection points are then imported into BIM software tools. The structural member, dimension, and material properties are inputted while the cross-section of the structural members is automatically generated for the irregularly shaped structural model (see Figure 2). At the same time, since there is an interface routine between the BIM software tool and the structural analysis software, a two-way interaction can be achieved between the BIM and analysis models. With a seamless transfer of the BIM data to the structural

工程案例

湖州喜来登温泉度假酒店（图 1） – 整个项目高101.2米、宽116米，呈指环型，目标建设为白金7星级酒店。结构设计方面，由于主要受力构件除了核心筒外，基本上都是曲线构件，对结构设计计算建模以及今后施工放线定位等带来了不小的影响。通过对方案阶段异型体量模型的数字化处理，求解出曲面的u，v曲线。各交点坐标信息被输入BIM软件工具中，同时赋予各结构构件的横截面信息和其他尺寸、材料信息，进而自动生成异型结构模型（图 2）。同时，基于BIM软件工具与结构分析软件的接口程序，BIM模型与分析模型实现双向联动。BIM数据无缝传递到结构分析软件，计算后的结果也可以通过该程序返回以更新原BIM模型（图 3，图 4）。这种高效的方式不但解决了空间异型的结构建模准确性问题，同时极大的提高了建模–计算之间的数据连贯性。

在施工阶段，三维设计数据经过设计方与深化厂家的合作，完全在模型上进行论证与深化。并借助数控技术无缝传递设计数据，完成生产加工与预拼装，更好地确保这一复杂结构的高完成度。同时，在现场依靠先进的三维激光扫描技术，实时地对

analysis software, the analysis results can also be returned through the program and update the BIM model (see Figures 3 and 4). Such an efficient method not only solves the accuracy problem of structural modeling in an irregular shaped space, but it also greatly improves the consistency of modeling-calculation data.

During the construction phase, the design team and detail manufacturers can cooperate through three-dimensional design data and models to demonstrate and develop the project progressed entirely on the model. Design data can be seamlessly transferred through Computerized Numerical Control (CNC) to complete the production, fabrication, and pre-assembly to better ensure a high level of completion of this complex structure. At the same time, with the support of the advanced three-dimensional laser scanning technology in the field, real-time supervision of the construction quality can be obtained to provide technical support for the high-quality installation and completion of critical structural, mechanical (see Figure 5), and other components.

Figure 1. Huzhou Hilton Resort & Hot Springs Hotel
图1. 湖州喜来登温泉度假酒店

Two-Dimensional Design and Construction Drawings

For thousands of years, drawings have been an intermediary for architects and engineers to present design and construction processes. Through drawings, a bridge for information transference can be established between the designers and the clients.

In ancient Egyptian times, when mankind had not invented paper yet, the Egyptians vividly expressed their residential spaces through murals. In 105 AD, Cai Lun invented a papermaking technology and was introduced to Europe around the twelfth century. To date, drawings have been used to express and guide the actual construction for thousands of years in history. After the Industrial Revolution, both construction drawings and shop drawings by professional manufacturers will form the medium in the design and construction process. On one hand, manufacturers can generate shop drawings for each component through further development of the architect's construction drawings and then produce related prefabricated components and assemblies in the shop. Finally, manufacturers will transport the drawings to the site for assembly afterwards. On the other hand, based on construction drawings, construction workers can use other materials (such as bricklaying, pouring concrete, riveting-bolted or welded steel components forming steel structures, etc.) in the field to complete the construction process.

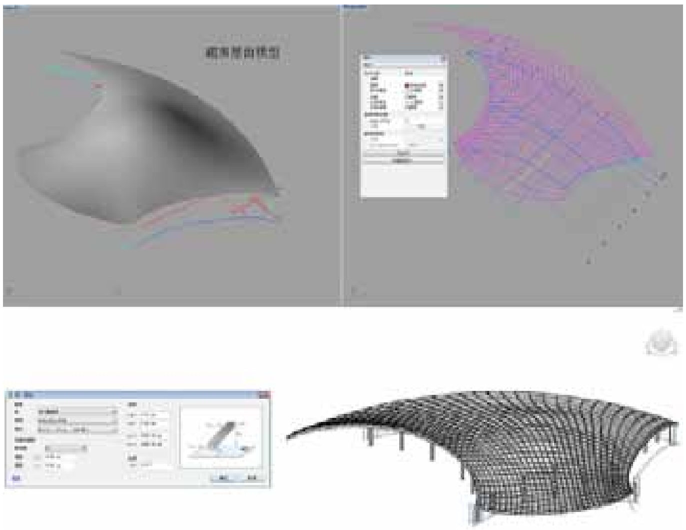

Figure 2. irregularly shaped models automatically calculated
图2. 异型结构模型自动生成

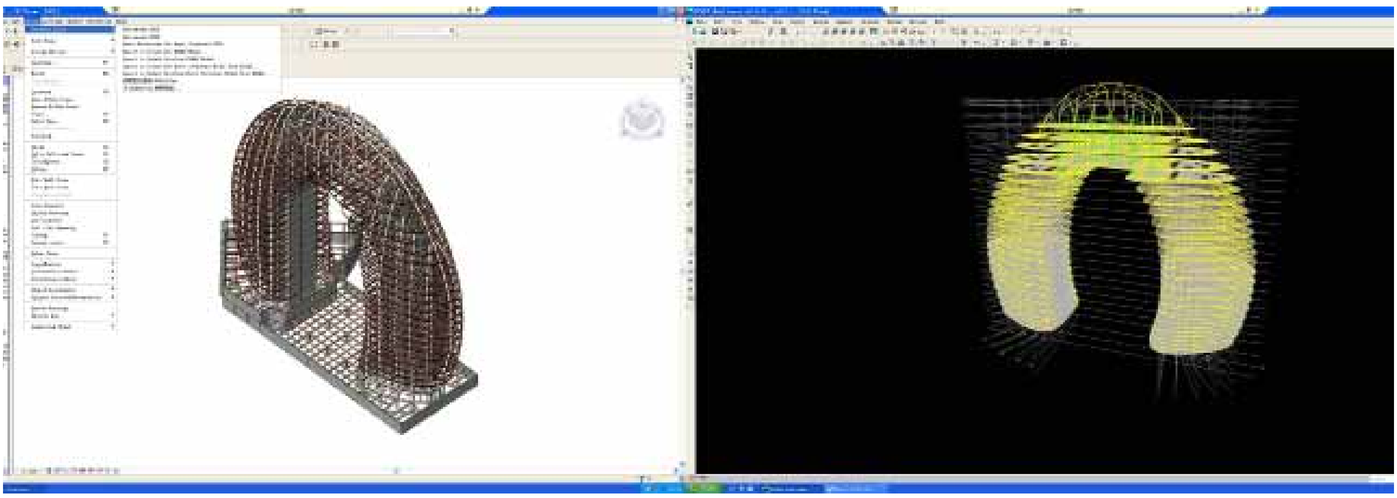

Figure 3. BIM model and structure analysis model two-way interaction
图3. BIM模型与结构分析模型双向联动

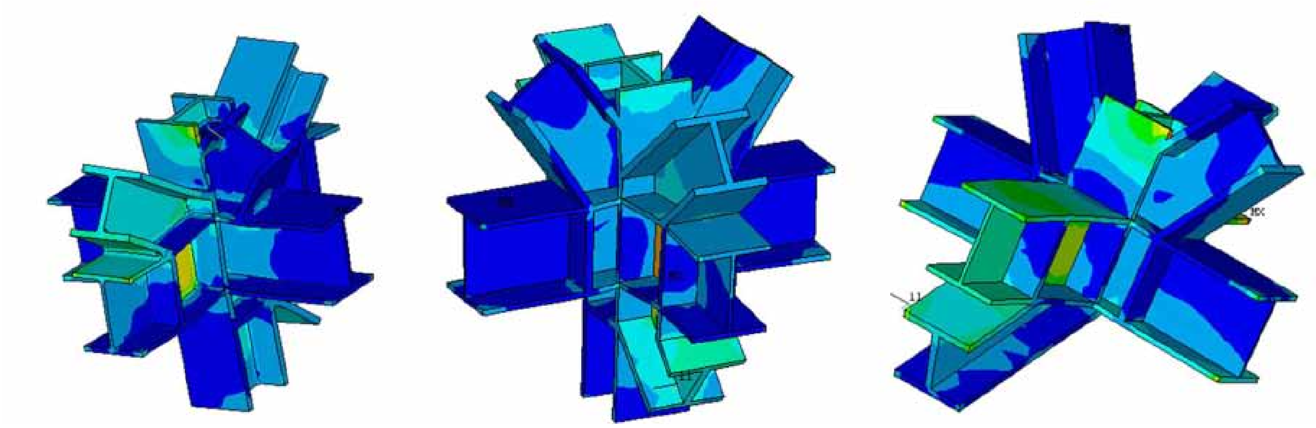

Figure 4. stress map of the detail connection
图4. 节点应力云图

In the transitional construction process based on two-dimensional drawings, the most important factor is orientation. Traditional construction orientation methods are based on the Cartesian coordinate system, such as the use of the plumb line, snap line and such, to orientate verticality and horizontality. These methods are very simple and effective for buildings that can be articulated by two-dimensional drawings. However, there are many difficulties to cope with for the increasing amount of architectural forms with three-dimensional complexities. Because of this, traditional two-dimensional drawing methods limit the exploration of architectural creation possibilities to the architects while increasing the difficulty in the fabrication process and field construction.

Additionally, two-dimensional representations of the same object can be expressed in different drawings from different participants repeatedly, which being expressed many times conduces to a non-distinctive information source. Due to uncontrollable factors that can frequently occur in the design and construction process, modification tends to occupy a higher proportion of the entire workload. As the information in two-dimensional drawings is relatively independent, this modification process can become challenging and have no relatedness in the process of updating information. In regards to traditional work methods that rely on drawing sheets, the modification workload will be multiplied as the identical design content is repeatedly illustrated in various drawings while simultaneously increasing the possibility of error. If an object requires modification but is repeatedly illustrated in multiple drawings, and if all of the drawings have not been fully revised correctly or even if it is properly modified but not in all related sheets or correlated drawings, the efficiency and quality of the work as a whole can be greatly hampered.

施工品质进行监控，为高品质地完成关键部位的结构、机电（图5）等安装任务提供技术支援。

二维设计与施工图纸

千百年来，图纸一直是建筑师和工程师表达设计与建造过程的中间媒介，通过图纸，设计者与营造者之间建立起了一座信息传递的桥梁。

在遥远的古埃及时期，由于当时人类还没发明纸张，埃及人用壁画的形式生动地表达了他们的住宅空间。公元105年，蔡伦发明了造纸技术，并于12世纪前后传入欧洲。至今，图纸一直被用来表达和指导实际建造已有近千年的历史。在工业革命后，施工图纸和专业厂家绘制的构件加工图纸共同组成了设计与建造过程中的物质媒介。一方面，厂家深化建筑师的施工图形成构件加工图纸，在工厂中加工出相应的预制构件和组件，然后运送到现场组装；另一方面，施工人员根据施工图纸在现场操作另外一些实体物质（如砌砖、浇筑混凝土，铆接-栓接或焊接钢构件形成钢结构等）完成建造过程。

在传统的基于二维图纸的建造过程中，首要的就是定位，传统的施工定位主要是基于笛卡尔直角坐标系统的放线法，例如采用铅垂线、弹墨线等定位垂直度和平直度。这些方法对于二维图纸可以清晰表达的建筑物来说，非常简便和有效。可是对于越来越多的三维复杂建筑形态来说，就显得捉襟见肘。正因如此，传统的二维图纸方式限制了建筑师对于建筑创作中各种可能性的探索，也使得加工制作和现场建造等过程变得十分困难。

另外，二维图纸的表达方式，由于同一被表达对象在不同的图纸上要被不同参与方表达多次，导致信息来源的不唯一性。设计与建造过程中由于不可控因素频繁发生，修改往往占据整个工作量

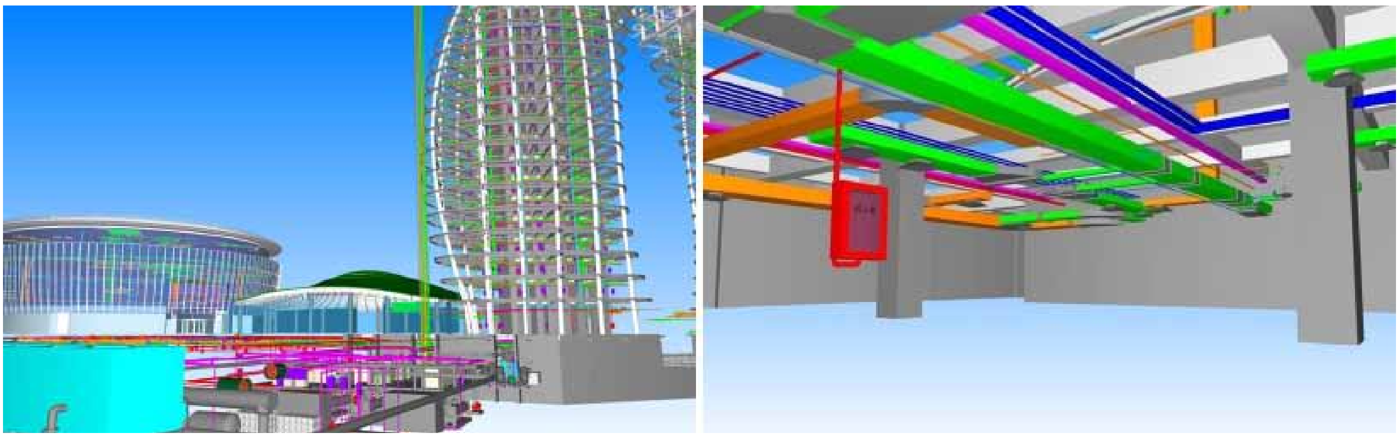

Figure 5. Mechanical model
图5. 机电模型

The Advent of BIM

With the development of computer information technology, information transfer no longer relies solely on traditional two-dimensional drawings. Instead, directly building a three-dimensional model via computer to digitally transfer the information to complete the design, manufacture, assembly, and testing processes can achieve the final product. However, the amount of information contained in such three-dimensional computer models is still limited, often only describing the visual information of the spatial configuration, effect illustrations, and such. The repeated modeling and information transfer for each project participant is based on various work requirements, in which the overall collaboration process is still in an unorganized, isolated state.

It is in these conditions that the concept of the Building Information Model emerges. The so-called "Building Information Model" (referred to as BIM) refers to the exploration process of the building's critical physical characteristics and features illustrated digitally prior to construction. It integrates construction projects with all of the relevant information and can be applied to the whole process of design, building, and management. It helps improve project delivery speed, lessen project costs, and reduce project risks. The creation of information is not limited to geometrical visual information, but it also includes a large quantity of non-geometric information such as performance, various technical constraints, product information, and other material parameters.

"Design-Construction" Collaboration Based on Information

BIM is based on the information contained within a three-dimensional model. Three-dimensional modeling is only the starting point of BIM, while the information within are maintained throughout the whole process of design, production, and construction. The essence of both two-dimensional drawings and three-dimensional models are an expression of engineering. BIM is the intermediary language for design communication and construction data transfer.

Essentially, the building information model is the third phase result of the three-dimensional CAD technology development from the mechanical manufacturing field, which is parametric solid modeling technology. Some BIM-based software tools are already equipped with the preliminary fourth-generation variable solid modeling technology concepts. Parametric design not only accurately describes and defines various properties of the elements, but it also drives through parameter dimensions, constraints, and associated designs.

Even though complex geometries can be virtually expressed in the computer with three-dimensional technologies, if designers still rely on traditional construction techniques, then it will be difficult to convert this into reality. CNC fabrication is an important technological invention that makes direct manufacturing processes that rely on three-dimensional data information possible. Since the data is coherent and non-destructive, it greatly reduces processing errors of building components. Three-dimensional data from the model is converted into the corresponding CNC machine tool's NC code and imported to the control system of the CNC machine tools. The CNC machine tools utilize these three-dimensional instructions directly to prepare the machine tools for cutting, milling, drilling, and other automated machine processes. The finished components are digitally encoded and pre-assembled in the shop or delivered to the site for installation. During the installation process, in order to ensure accuracy, three-dimensional laser scanners will be used for real-time digital

中较高的比例，二维图纸都是相对独立的信息，不能使这些过程信息具有关联性。以图纸为工作对象的传统工作方式，由于同一设计内容在不同图纸上重复出现而使得修改的工作量成倍增加，更使得出错的机率也成倍增加。同一被表达多次的对象，如果不能正确的在图纸上被完全修改，或虽然被正确地修改了，但没有处处得到修改或关联，这对整个工作的效率和质量都是极大的限制。

建筑信息模型的出现

随着计算机信息技术的发展，信息传递不再是仅仅依靠传统的二维图纸，而是直接通过计算机构建三维模型，数字化地传递信息完成设计、加工制作、装配和检测过程，实现最后的产品。然而，此类三维计算机模型所包含的信息量仍然是有限的，往往是对于空间形态、效果展示等的视觉上的信息描述；各项目参与方也根据不同的工作要求，重复建模和传递信息，整个协作过程仍然处于一种无序、孤立的状态。

建筑信息模型的概念在这种条件下得以出现。所谓“建筑信息模型”（Building Information Modeling，简称BIM），是指在建造之前以数字化方式对建筑物关键物理特性和功能特性进行探索的综合过程。其集成了建筑工程项目各种相关信息详尽的数字化描述，可以应用于设计、建造、管理的全过程，帮助提高项目交付速度、减少成本，并降低项目风险。在这里，信息的内涵不仅仅是几何形状描述的视觉信息，还包含大量的非几何信息，如性能等技术参数和产品信息等物资参数。

基于信息的“设计-施工”协作

BIM的基础是基于信息的三维模型，三维模型是BIM的起点，而其中的信息则贯穿设计、制作与施工的全过程。无论二维图纸还是三维模型，其实质都是一种工程表达方式，是进行设计交流与建造数据传递的中介语言。

建筑信息模型从实质上是借鉴了机械制造领域三维CAD技术发展的第三阶段成果，即参数化实体造型技术。其中部分基于BIM的软件工具已具备初步的第四代变量化实体造型技术思想。参数化设计既能精确描述和定义构件的各种属性，又可以通过参数尺寸驱动、约束和关联设计。

虽然三维技术实现了复杂形体在计算机上的虚拟表达，但如果依靠传统的施工技术，仍然较难将其转换为现实。数控加工技术作为一项重要的技术发明，使得依靠三维数据信息直接进行加工制作变为可能。由于数据的连贯一致与无损性，大大减少了建筑构件的加工失误。三维数据模型通过转换成相应的数控机床NC代码，并传入数控机床的控制系统，数控机床依据三维指令直接驱动机床进行切、削、铣、钻等自动化加工。加工制作完毕的构件通过数字化编码后，在工厂预拼装或被运送至现场安装。安装过程中，为保证精度，采用三维激光扫描仪进行实时数字化定位，将获得的点云信息同计算机中的三维模型进行数据整合与校对。整个过程大大提高了三维模型的重用率和设计与施工的准确一致性。

结语

基于建筑信息模型的技术革新，不仅改变了传统设计方法，而且对当前钢结构加工制作、现场施工和质量控制技术也有了新的提升。设计和建造开始关注用看不见的“数字”去生成和建造一个建筑产品，它不但打开了长久以来限制对建筑形态和空间创作的枷锁，更使得设计与施工变得合作无间。

positioning to receive point cloud data which will be integrated and calibrated with the three-dimensional model on the computer. The whole process greatly increases the reuse rate of the three-dimensional model and the consistency of design and construction.

Conclusion

BIM technological innovations not only changes traditional design methods but also improves the current steel structure manufacturing processes, site construction, and quality control technologies. Design and construction is starting to focus the invisible "digital" elements in order to generate and create architectural products. Not only does it break the shackles of the limitation to the architectural form and space creation through the ages, but it also closes the collaboration gap between design and construction.

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