

建筑师的元符号： 建筑制图如何借鉴大数据可视化

A META-NOTATION FOR ARCHITECTS: HOW ARCHITECTURAL DRAWINGS CAN BORROW FROM BIG DATA VISUALIZATION



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摘要

设计过程中所涉及的信息的数量和复杂性正在成倍增长。然而，目前建筑学中所使用的符号规范却不能够有效表达设计系统或模型，仅能记录它们得出的单一的结果。在科学领域，特别是那些能够处理“大数据”的计算模型，已经在多元信息可视化问题上探索了相当长一段时间。通过研究大数据可视化面临的挑战及相应的解决方案，建筑师可以重新制定制图规范，该规范中将包含元符号——这一表示法可以对设计及其中的变量和限制因素系统进行描述。

关键词

建筑绘图；大数据可视化；设计过程

ABSTRACT

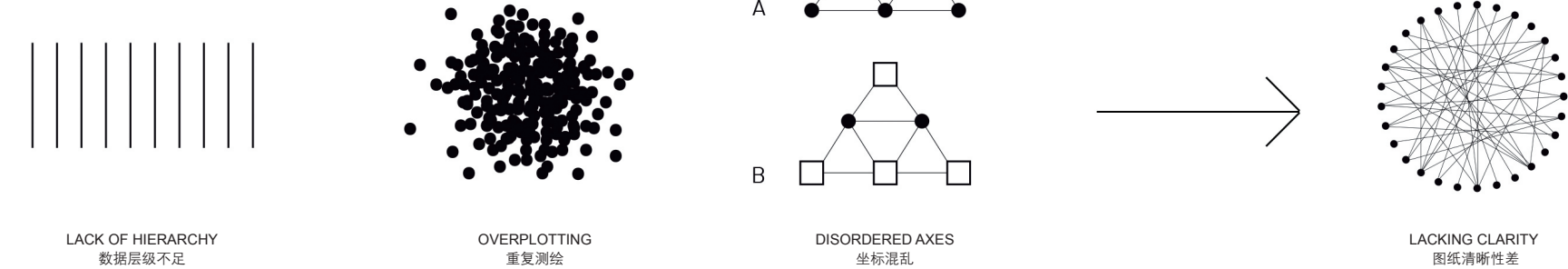
The amount and complexity of data navigated during the design process is growing exponentially. Yet, notation conventions in architecture fail to record our design systems or models and default to documenting just the singular output they produce. The scientific community, particularly those dealing with “big data” computational models, has been wrestling with multivariate information visualization for quite some time. By studying the challenges and solutions to big data visualization, architects can re-invent drawing conventions to include meta-notation — a notation to describe the design and its underlying system of variables and constraints.

KEY WORDS

Architectural Drawing; Big Data Visualization; Design Process

译 田东

TRANSLATED BY Tina TIAN



1. 大数据可视化面临的挑战

1. Challenges in big data visualization

设计过程中所涉及的信息的数量和复杂性正在成倍增长。然而，目前建筑中所使用的符号规范却不能够有效表达设计系统或模型，仅能记录它们得出的单一的结果。在科学领域，特别是那些能够处理“大数据”的计算模型，已经在多元信息可视化问题上探索了相当长一段时间。通过研究大数据可视化面临的挑战及相应的解决方案，建筑师可以重新制定制图规范，该规范中将包含元符号——这一符号表示法可以对设计及其中的变量和限制因素系统进行描述。

近来，我与肖恩·皮尔斯·科特勒博士共同指导了一组由建筑师和生物医学工程师组成的团队，对大数据表现问题进行了研究。我们研究的初衷是想改变科学图形和图表的形式，因为它们已不再是有效的沟通工具，这一点在涉及庞大的数据处理的实验中体现得尤为突出。这个项目引发了我们与其他生物医学研究人员展开了一系列讨论，对他们在使用计算机模型和大量数据之时所面临的严重的交流问题进行了探讨。虽然对于成果的交流是重要的，但或许，在得出这些成果的模式上的交流更为关键。只有了解了这些算法中的关键变量和过程，研究员们才能够对结果进行评价。这些问题已同样出现在建筑设计领域，因为复杂的建筑模型对于生成的形式而言既是机遇亦是约束，其也推动了

研究得以进行。

1 滞后期：与印刷术相似的局面

将建筑中设计、建造和分析的复杂技术过程相整合是一个被一再强调的议题。从基于关联性模型的协调建设，到动态响应式建筑系统、机器人和3D打印数字化建造、优化设计、传感与分析，我们在大数据方面的协调能力和在算法上的交流能力令我们意识到，数据从未像现在这么重要。然而，建筑中新的制图和符号形式的发展却大大滞后于我们灵活适应新技术的能力。我们在数据系统方面并不能进行有效的交流，其主要原因是建筑制图仍然以最终绘制成图为目的，而忽略了图纸得以生成的关键性要素——规则和数据。

先进的技术和停滞不前的表现形式之间已存在明显差距，这种情况与印刷术使用初期时的现象十分相似。根据伊丽莎白·爱森斯坦及其后布鲁诺·拉图尔的记载，“印刷术的引入和极度逼真的图片的出现之间的时间滞后是个令人费解的现象。起初，印刷术仅简单地应用于草药植物图、解剖图、地图、宇宙哲学图像等已陈旧的事物的印刷——这些图像在后世看来也是错误百出的。”^[1]相关技术的形成要远早于可视化

形式的发展。拉图尔继而总结到：“爱森斯坦一次又一次地指出……在印刷术出现之前，各种已存在的智慧成就——有条理的怀疑主义、科学方法论、收集数据、辩驳、理论形成——都已在包括地理学、宇宙学、医学、经济学在内的各个学科有过尝试。但每一个成就都仅局限于本学科内，并且都仅是昙花一现；而这正是因为这些成果无法传播到其他领域，其他领域的成果也无法传播进来。”^[1]

2 建筑面临的问题

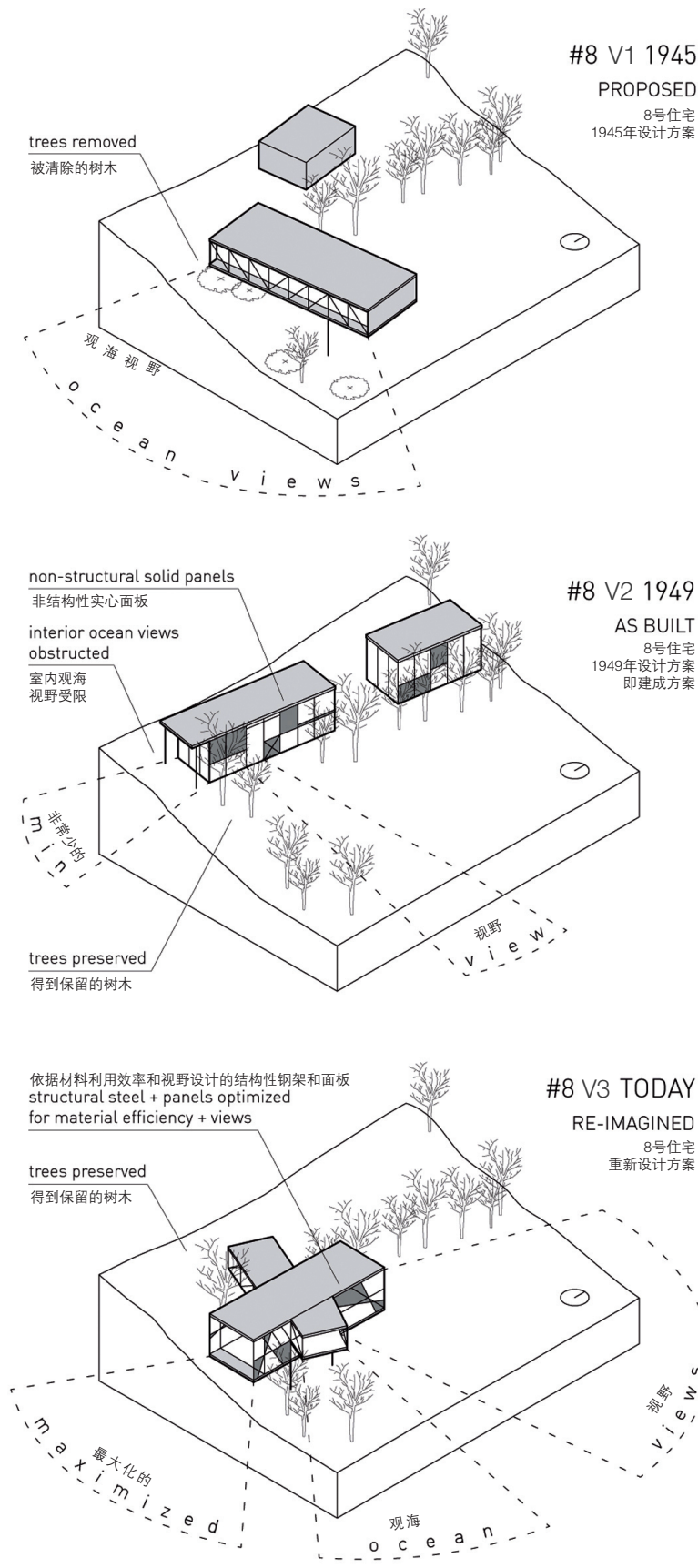
在当代建筑领域中，我们正处在一个与前文相似的滞后时期。我们正在探索、分析，并构建越来越复杂、功能机制越来越强的系统，但我们的视觉输出仍大多停留在对材料和维度的文字表述，或视觉意象上。任何项目的设计智慧成果仍然无法得到广泛而长久的传播。这导致知识无法有效地在学科间转达、转换，也使得在建筑建造和翻新过程中出现“翻译”障碍。许多人认为，通过直接对加工制作进行设计以及BIM建模，数字工具可以消除从图纸到建造过程中的所有“翻译”问题。而且这也很快迎合了低成本、大批量定制的未来发展方向。然而，在实践中，我们却面临着另

一番境况。与制造者和工程师的前期交流对任何先进技术的发展来说都非常重要。这种交流通常依赖于二维图纸和草图，它们能够快速传达思想、设计理念和性能极限。通过三维模型、施工图和二维制作图的表达，设计方案不断成形，这个过程中——其中设计者需要对空间与材料性能不断进行平衡——的大部分智力投入都在无形中被转化成了一种单一的输出。而在后端，承包商和分包商在制作、组装或安置的过程中不停地做出“翻译”决定。然而，如果不能了解原始的设计思想，那么在一些关键性的问题上就不能做出精确的“翻译”。

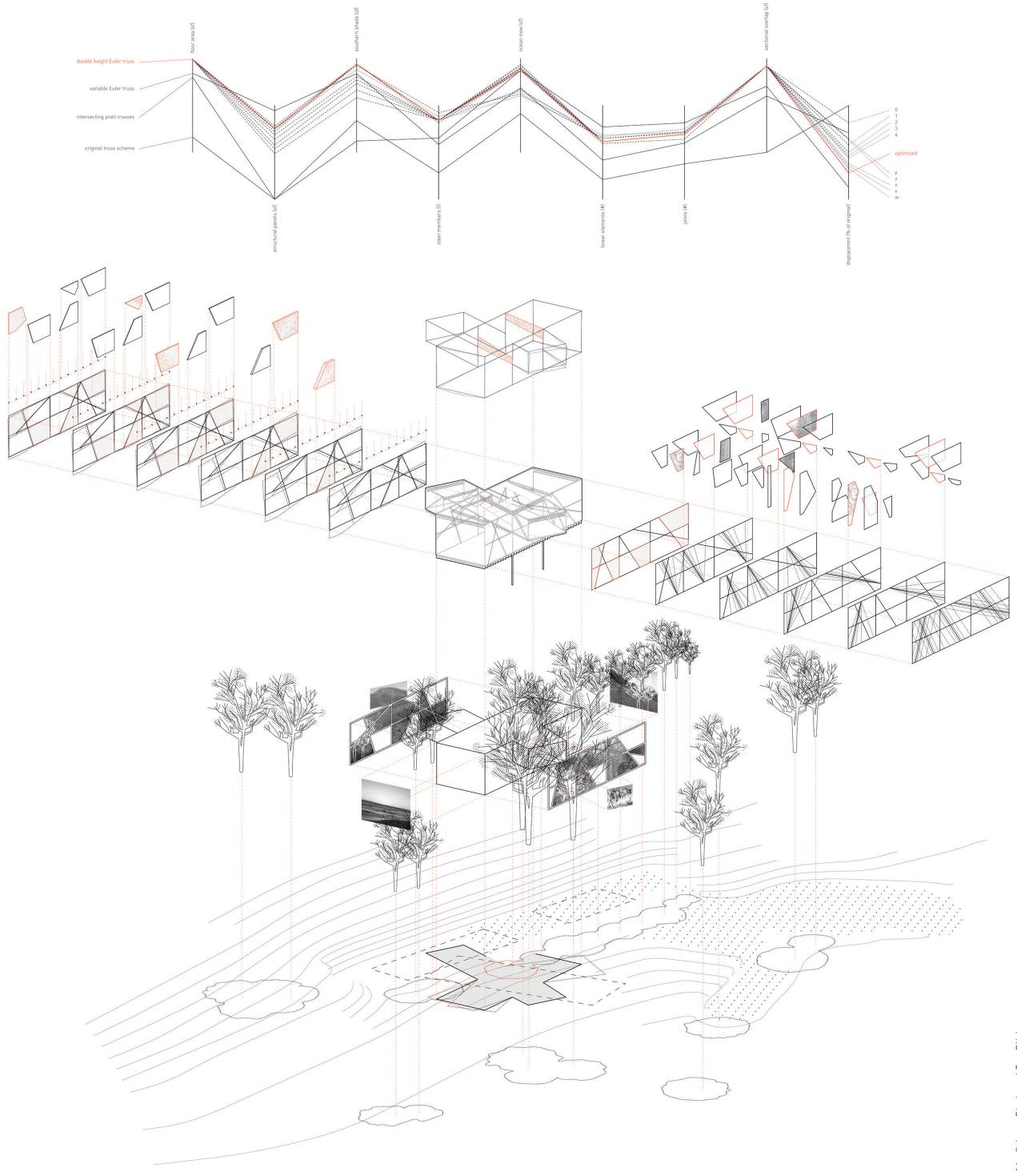
让我们来设想一下另一种情况：如果我们拥有一套能够对某一项设计的制作过程或模型进行实际记录的“设计形成过程图”的话，那会怎样？这些元图纸将可以对设计过程中的关键因素进行记录。什么是空间或视觉的意图？什么是可以推敲的关键性的物质考虑——可称重玻璃面板的高度限制、跨高比，或消防通道的红线后退？如果我们能对这些极为重要的变量和限制因素进行重新设定，那么设计和施工团队间的沟通将会发生多么大的改进啊！届时无论是学生还是从业人员，都将能够领会到任何设计先例中的智慧，也可以知晓这些先例所面临的挑战。

3 绘制模型：多元信息可视化技术

拉图尔借用了弗朗索瓦·达高涅的观点并进一步指出“任何科学学科都是基于某种视觉和书面语言发展起来的，只有这些语言的出现才能让学科脱离其混沌的过去。”^[2]



- 8号住宅案例的三个版本对比图：本文作者通过对8号住宅进行重新设计，对建筑结构和体量进行了优化，以对原有树木进行保留，并将观海视野最大化。
- 8号住宅案例重新设计方案
- Three versions of Case Study House #8: The author's re-imagined house #8 optimizes structure and mass to preserve existing trees and maximize ocean views.
- Case Study House #8 V3



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建筑学并不是唯一一个需要寻求重新建立一种新的、能够适用于数据系统新局面的视觉语言的学科——特别是那些对于大数据模型苦苦探索的学科，在输出的多次迭代及形成迭代的多变量系统方面的交流正日益重要。

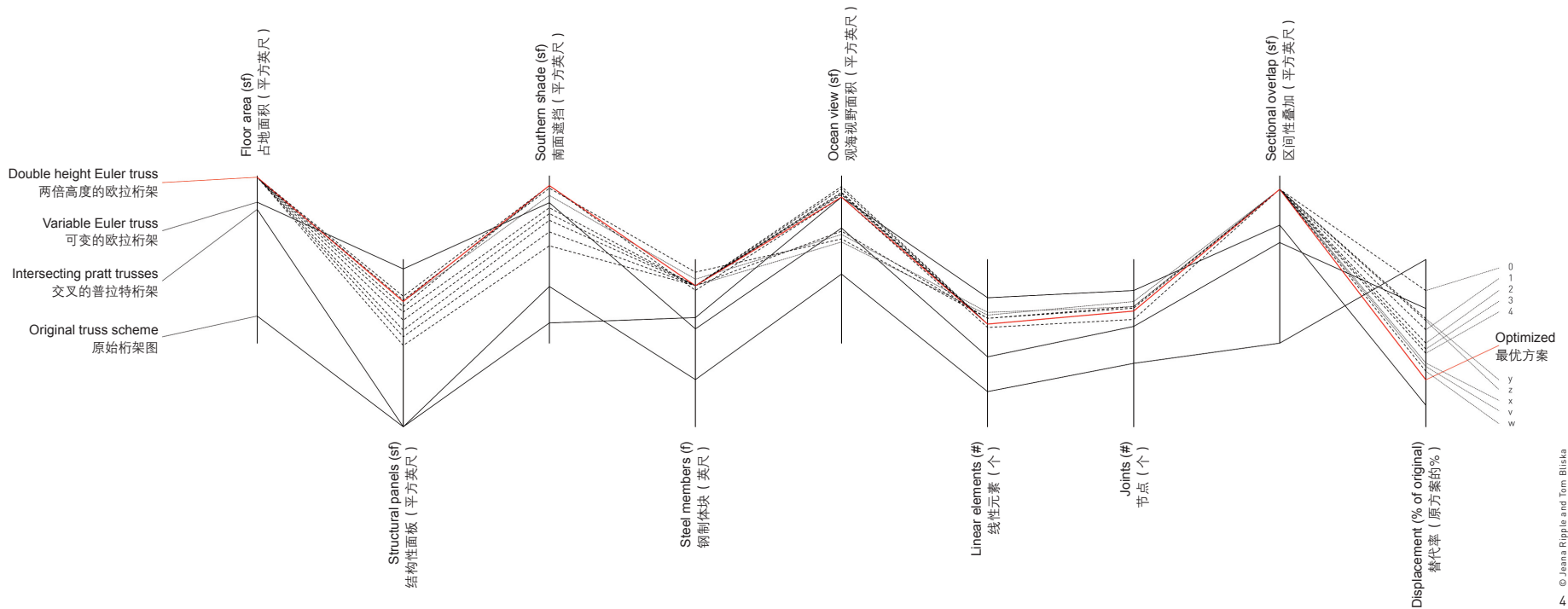
对多变量系统的跨学科研究正面临着类似的挑战（图1），包括数据层级不足、（在信息尺度和密度的处理上存在）重复测绘、坐标混乱等问题。^[3]用于解决上述这些问题的技术——从数据简化/减少算法，到动态的用户交互界面——都需要考虑众多可调节变量组合。^[3]

诸如平行坐标等传统可视化技术也在科学领域广泛应用，这些技术有助于我们找到对建筑元符号研究的切入点。当图算法诞生之后不久，平行坐标于1885年第一次出现在科学文献中时，数据样本以穿越平行的变量坐标轴的线条的形式呈现。^[4]这一假设已得到了更高维度的成功检验^{[4][5]}；这一方法——无论是应用于简单还是复杂的数据环境中——可以使研究人员观察变量对于参数的影响。此外，通过交换平行坐标轴的顺序，研究人员可以识别变化趋势，或对无关变量进行剔除。

4 翻译：一个案例研究的方法

为了开始检验元符号的可能性，我与一名研究助理对参数化分析系统的常规制图规范进行了改变。我们受即兴音乐乐谱和计算机模型可视化的启发，用它们对设计过程中的逻辑、表现与演变进行记录。

这名学生助理提出了一种参数化系统，



以对1945年发表于《艺术与建筑》杂志的埃姆斯住宅（即8号住宅案例）的原始未建成方案进行了重新解读。^[6]为了对开放场地和原有树木进行保护，埃姆斯住宅最终被重新设计。据称，新的住宅使用了原建筑的结构材料；然而因为新旧住宅截然不同的建筑结构特点，这一方案备受质疑。^[7]在这种情况下，这名学生设计了一座桥式住宅，通过对结构、材料进行有效利用、最大程度地保护场地原有树木，并尽可能地使住宅朝向其临近的太平洋海岸，重现了埃姆斯住宅的原始设计（图2）。

图纸记录了项目中的设计思考（图3），将一系列设计迭代与它们的性能参数相结合，并反映了它们对场地和视线的影响。通过使用平行坐标，在考虑材料利用效率和设计重点的基础上，绘制出了一系列主桁架结构图（图4）。这些带有偏移量的坐标轴，可反映参数是否理想：理想的参数位于坐标

图上方，不理想的参数位于坐标图下方。例如，在理想情况下，为了使具有观海视野的住宅面积最大化，钢制体块的体量将缩小。由此形成的最终建筑——根据平衡设计和性能变量得出的最佳设计方案——的图纸文件记录了桁架结构中的一系列可选变量。它展示了高压压力板在每一次迭代中的性能（图5）、场地视线障碍（树木）之间的关系（图6），以及在建筑体量的选址决策和现有树木之间的冲突（图7）。

该项目提出的绘图与标注方法突显了建筑性设计重点、设计过程的演变和设计体系中的行为。

5 走向即兴

当代设计中的数据体系有着更高的精度要求，需要更快的生产节奏，能够对加工制作进行直接设计，并要求具有法律约束力的

模型和文件。在这种设计过程的新局面中，我们应该拥有更多的机会去成功地即兴发挥和调整我们的方案，以使它们的魅力得到传播。当我们对符号规范进行扩展，以使设计体系中的数据得到最有效记录，这样的“翻译”才能成为现实。**LAF**

致谢

感谢本文中8号住宅重新设计方案相关图纸的绘制者Tom Bliska，以及对本文中所述项目做出贡献的研究员：Joshua Aronson、Joseph Walpole、Elizabeth Obrien、Angela Jividen和Will Green。同时感谢和我共同指导了生物医药研究团队的重要的导师肖恩·皮尔斯-科特勒教授。最后，我还要感谢弗吉尼亚大学建筑学院院长Kim Tanzer和杰斐逊基金会对本项目的支持，以及Tanzer院长、Cammy Brothers和Ghazal Abbasy在上述问题上所带来的生动活泼的讨论。

4. 8号住宅案例重新设计方案的平行坐标图细部，图中展示了依据材料利用效率和设计重点而绘制的主要结构性桁架。
4. Parallel Coordinates detail shows primary structural trusses are charted according to material efficiency and design priorities, Case Study House #8 V3.

A META-NOTATION FOR ARCHITECTS: HOW ARCHITECTURAL DRAWINGS CAN BORROW FROM BIG DATA VISUALIZATION

The amount and complexity of data navigated during the design process is growing exponentially. Yet, notation conventions in architecture fail to record our design systems or models and default to documenting just the singular output they produce. The scientific community, particularly those dealing with “big data” computational models, have been wrestling with multivariate information visualization for quite some time. By studying the challenges and solutions to big data visualization, architects can re-invent drawing conventions to include meta-notation—notation to describe the design and its underlying system of variables and constraints.

I recently partnered with Dr. Shayn Pierce-Cottler to guide a team of architects and biomedical engineers in addressing problems with big data representation. Our research intention was the revision of scientific graph and chart formats that were failing as effective communication tools, particularly when large amounts of data were involved in an experiment. This project inspired a series of discussions with other biomedical researchers on the critical communication challenge they face using computational models

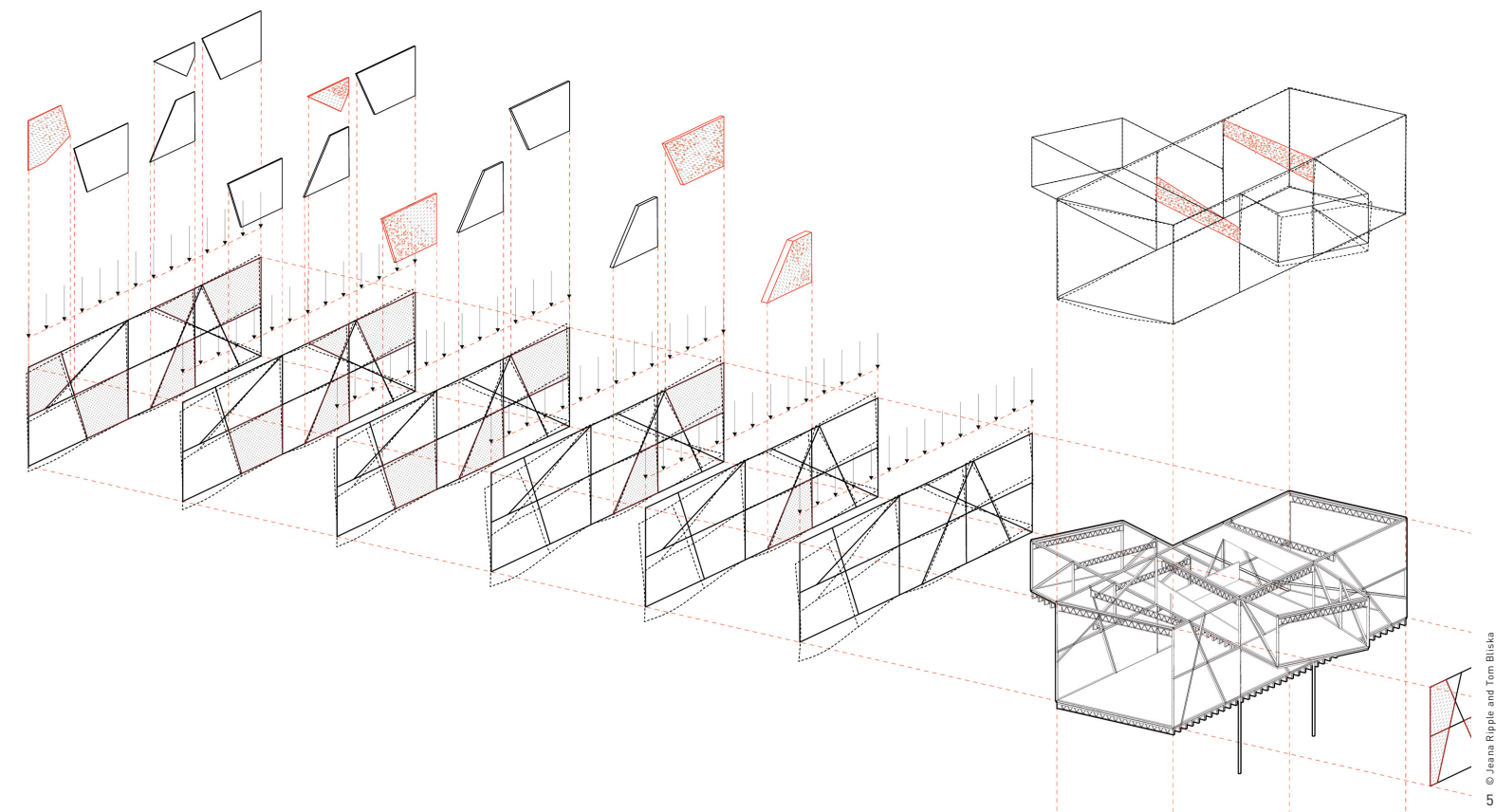
and large quantities of data. Although communication of results is important, perhaps more critical is communication of the model used to generate them. Only by understanding key variables and processes embedded in their algorithms, would fellow researchers be capable of evaluating results. These issues have clear parallels to architectural design, given the prominence of complex architectural models used to weave opportunities and constraints into a resulting form, and prompted the following research.

1 Lag-Time: Learning Lessons from the Printing Press

The integration of complex technical processes in design, construction, and analysis of architecture has become commonplace. From construction coordinated by associative models to dynamically responsive building systems, robotic and 3D printed digital fabrication, performance optimization, sensing and analytics, our ability to coordinate big data and communicate the algorithms managing that data has never been more critical. However, the development of new forms of drawing and notation in architecture is significantly lagging behind

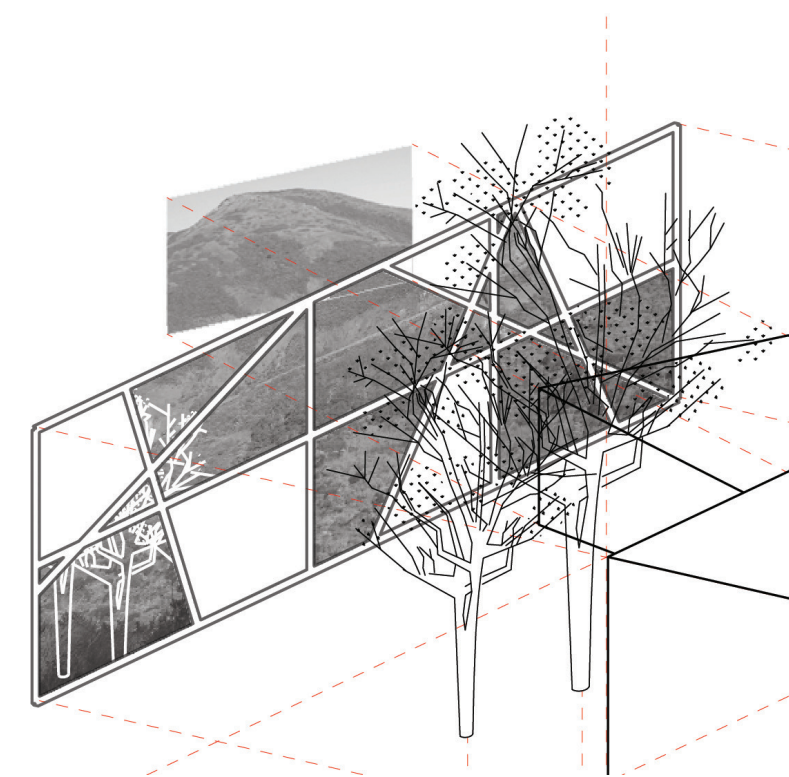
our nimble adaptation of new technology. We are not communicating our data systems effectively, primarily because the subject of architectural drawings is still the object rather than the rules and data that produce it.

This gap between advancing technology and stagnant forms of output is comparable to a phenomenon that occurred during the early use of the printing press. According to Elizabeth Eisenstein and later summarized by Bruno Latour, there was a “puzzling phenomenon of a lag time between the introduction of a printing press and the beginning of exact realistic pictures. At first, the press is used simply to reproduce herbaries, anatomical plates, maps, and cosmologies that are centuries old and that will be deemed inaccurate much later.”^[1] It took time for the form of visualization to catch up with the capacity of the technology. Latour goes on to summarize what Eisenstein “shows again and again... that before the advent of print, every possible intellectual feat had been achieved — organized skepticism, scientific method, refutation, data collection, theory making — everything had been tried and in all disciplines: geography, cosmology,



5. 8号住宅案例重新设计方案中的桁架变量与板材使用细部。
6. 8号住宅案例重新设计方案中的住宅结构与场地视线关系。

5. Truss Variations and Panel Utilization Detail, Case Study House #8 V3.
6. Relationship between house structure and views onsite, Case Study House #8 V3.



medicine, economics, and so on. But each achievement stayed local and temporary just because there was no way to move their results elsewhere and to bring in those of others.”^[1]

2 The Problem for Architecture

In contemporary architecture, we are occupying a similar lag-time gap. We are exploring, analyzing, and building increasingly sophisticated and performative systems, but our visual output is still focused primarily on literal documentation of material and dimension or on the visionary image. The design intelligence achievements of any project are remaining largely local and temporary. This prevents effective

knowledge transfer in the discipline while also causing translation problems during construction or renovation.

Many assume that digital tools promise to eliminate all ambiguity from the process of translation from drawing to building through direct design to fabrication and BIM modeling. And it quickly follows that low-cost mass-customization is the way of the future. However, in practice, we experience a different reality. Communication with fabricators and engineers upfront is an important part of the development of any advanced technology. This communication typically relies upon 2-dimensional drawings and sketches as a way to quickly transmit ideas, design desires, and performance limitations.

As the design solidifies in the form of 3D models, construction documents, and 2D fabrication drawings, much of intelligence of the system — a balance between spatial and material performance — is invisibly absorbed into a singular output. At the back-end, contractors and subcontractors are making translation decisions during fabrication, assembly, and / or installation. Yet without access to the original system of design considerations, that translation occurs without full access to the issues at stake.

Let us imagine an alternative. What if a set of “Design Development” drawings actually recorded the process or model producing a particular design? These meta-drawings would need to

document key considerations in the design process. What is the spatial or visual intention? What are the key material considerations that might push back — height limitations to affordable glass panels, span to depth ratio, or fire code setbacks? If we could reconstruct the paramount variables and constraints, imagine the improved communication across design and construction teams. Imagine the ability of students and practitioners to access the intelligence and challenges of any design precedent.

3 Drawing the Model: Techniques in Multivariate Information Visualization

Referencing Francois Dagognet,

Latour claims that “no scientific discipline exists without first inventing a visual and written language which allows it to break with its confusing past.”^[2] We are not alone in our quest to reinvent a new visual language to communicate a new landscape of data systems. Particularly among those wrestling with big data models in the sciences, it is becoming increasingly important to communicate multiple iterations of output and the multi-variable systems that produce them.

Multi-variable systems across disciplines face a similar set of challenges (Fig. 1) including lack of data hierarchy, overplotting (managing the scale and density of information), and disordered axes.^[3] The techniques used

to address these issues, range from data simplification / reduction algorithms to dynamic user interfaces allowing for multiple, adjustable combinations of variables.^[3]

There are also widely used traditional visualization techniques in the sciences, such as parallel coordinates, that can provide useful starting points for experimentation in architectural meta-notation. Dating back to 1885 when it first appeared in scientific literature in the context of Nomography, parallel coordinates maps data samples as lines traversing parallel axis of variables.^[4] This basic premise has been successfully tested at higher dimensions,^{[4][5]} and the method, applied either to simple or complex sets of data, allows researchers

to trace the influence of variables across a field of parameters. Further, by swapping the order of parallel axis, one can recognize trends or eliminate trivial variables.

4 Translation: A Case Study Approach

To begin testing this potential, I worked with a research assistant to reinvent drawing conventions for a parametric analysis system. Improvisational music scores and computational model visualizations were used as inspiration to record the logic, performance, and evolution of a design system.

The parametric system developed by the student was a reinterpretation of the original unbuilt Eames case study house, first published in 1945 as case study house #8 in *Arts and Architecture*.^[6] The house was eventually redesigned to preserve the open site and existing trees. The new house allegedly used the same structural material as the original version, a claim that has been the subject of much doubt due to their vastly different structural characteristics.^[7] Nonetheless, operating in this context the student designed a bridge residence, interpreting the original to use structural material efficiently, maximize preservation of existing trees and take greater advantage of site lines toward the nearby Pacific coast (Fig. 2).

The drawing that documents the design considerations in this project (Fig. 3) ties a series of design iterations to their performance parameters, while documenting their relationship to the site and view-lines. Using parallel coordinates, a series of primary structural trusses are charted according to material efficiency and design priorities (Fig. 4). The axes are offset so that desirable parameters are high on the page, and undesirable parameters are low. For examples, ideally the cubic feet of steel would be limited while the square footage of ocean views is maximized.

Documentation of the resulting building — the most desirable compromise between design and performance variables — records a range of acceptable variations in truss configurations. It highlights the highly stressed panels in each iteration (Fig. 5) the relationship with view obstructions (trees) on-site (Fig. 6), and conflicts in siting decisions between building mass and existing trees (Fig. 7).

The project suggests methods of drawing and annotation to emphasize architectural priorities, the evolution of design processes, and the behavior of a design system.

5 Toward Improvisation

Contemporary data systems in design allow for more precision, demand faster

production of options, enable direct design to fabrication, and include legally binding models and documents. Within this new landscape of design processes, we should have greater opportunities to successfully improvise and adjust, while effectively communicating the elegance of our solutions. This translation will only be possible if we expand our conventions of notation to record the data of design systems most effectively. **LAF**

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